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THE SUNBURY SHALE OF OHIO.[1]

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INTRODUCTION.

OVERLYING the well-known Berea grit of Ohio is a black shale of somewhat variable though never very great thickness. It forms, however, a marked horizon in the Waverly series, and is very presistent in outcrop, extending from the Ohio river to northern Ohio, thence east nearly to the Pennsylvania line, and perhaps enters the state. On the south it crosses into Kentucky; but its extent in that state is not known. The older names, the Waverly black slate of Andrews and the Berea shale of Meek, when first applied to this shale were preoccupied, being in use for other geological divisions.

Professor Hicks at a later date gave the name "Sunbury shale" to a rather meager exposure on the bank of Rattlesnake Creek, about two miles east of the village of Sunbury, in the eastern part of Delaware county, Ohio, which is the first distinctive geographic name applied to this shale and therefore the one which, it appears to the writer, ought to be accepted for this formation. Recent examination of outcrops of this shale at different localities across the state has acquainted the writer with its characteristics, and furnished him with some facts which are perhaps worthy of record.

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[1] Published by permission of Professor Edward Orton, Jr., state geologist of Ohio.

HISTORICAL REVIEW.

There have been different opinions regarding the age of the Sunbury shale, and mistakes in regard to its correlation between the northern and southern parts of the state, so that it is thought advisable to give a brief review of its literature.

The shale was first recognized and named by Professor E. B. Andrews, in 1870, from outcrops in the Ohio valley in Adams and Scioto counties. He stated:

> There is a remarkable exception to the general character of the Waverly group, in a stratum of highly bituminous black slate, which is found about 137 feet above the base. It is sixteen feet thick, and remarkably persistent in the Waverly, and is said by my associates to be found in the northern part of the state. . . . . It contains the same mollusca, genera and species, as the black slate [Huron shale] viz., Lingula sub-spatulata M. & W., and Discina capax? White. It also contains similar scales of small ganoid fishes. Besides these fishes there are remains of larger fishes.[1]

To this shale Professor Andrews gave the name of Waverly black slate, and reported that it "is evidently a very widespread stratum. It is not only found extending through the Waverly formation to the north, but it evidently accompanies the Waverly rocks in their dip under the Coal-measures."[2]

In 1873, in describing the geology of Cuyahoga county, Dr. Newberry mentioned that the lower part of the Cuyahoga shale immediately overlying the Berea grit at Berea and Chagrin Falls contained "myriads of *Lingula melie* and *Discina Newberryi.* With these are a few scales of *Palæoniscus*, a Carboniferous ganoid and teeth of *Cladodus*, a Carboniferous shark."[3]

Under the description of Summit county occurs a similar statement, where it is reported that "at the base of the formation [Cuyahoga shale], however, immediately over the Berea grit, the Cuyahoga shale is sometimes crowded with millions of *Lingula melie* and *Discina Newberryi.*"[4]

In 1874, Dr. Newberry apparently correlated the Waverly black shale of southern Ohio with the Cleveland shale of northern Ohio. It will be remembered that the Bedford shale underlies the Berea grit in northern Ohio, and next lower is the Cleveland shale, which Dr. Newberry considered as the lowest division of the Waverly group. Dr. Newberry wrote that from northern Ohio "south to the Ohio river, the Cleveland shale is met with in various sections of the Waverly, but diminishing in thickness in this direction."[1]

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[1] *Geol. Surv. Ohio*, "Rept. of Progress in the Second District" [in 1869], 1870, p. 65.

[2] *Ibid.*, p. 66.

[3] *Rept. Geol. Surv. Ohio*, Vol. I, Pt. I, pp. 185, 186.

[4] *Ibid.*, p. 212.

And in reference to Professor Andrews' report of 1870 is the statement that he "mentions in his report that two fossils, *Lingula subspatulata* and *Discina capax*, are common to the Huron shale and the 'Waverly black slate' (Cleveland shale). This is probably an error of identification as, so far as yet known, the fossils of the two formations are quite distinct."[2]

The above interpretation of Dr. Newberry's correlation is supported by Dr. Orton's account of the Waverly group of Pike county, in which he states that:

> Immediately above the Waverly quarries comes in a very interesting formation, to which attention has been repeatedly called in the previous reports of the survey. The formation in question has been designated by the chief geologist the "*Cleveland shale*," and by Professor Andrews the "*Waverly black slate*." It consists of a black shale more highly charged with bituminous matter than the great black slate below it, the proportion sometimes rising as high as 24 per cent. Unlike the slate below it, viz., the Huron, it is often highly fossiliferous. Two species of brachiopods are especially abundant in it, viz., *Discina capax* and *Lingula sub-spatulata*. The remains of fishes are also of frequent occurrence. Its thickness, as measured in the Scioto valley, varies from seventeen and a half feet to twenty-seven feet.[3]

Dr. Orton also describes this black shale in his account of the geology of Ross county, and correctly reported the names of the two fossils which are abundant in the shale. His account is as follows:

> The greatest thickness yet observed in this formation is found in Franklin township, near the mouth of Stony Creek, where it measures not less than twenty-seven feet. It is charged at this point with its characteristic

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[1] *Rept. Geol. Surv. Ohio*, Vol. II, Pt. I, "Geology," 1874, p. 93.

[2] *Ibid.*, p. 96.

[3] *Ibid.*, p. 624.

fossils, *Lingula melie* and *Discina Newberryi*, and the remains of fishes, often in an excellent state of preservation, can hardly be called rare. The teeth and the plates are the parts generally shown.[1]

Professor N. H. Winchell, who wrote the geological description for several counties in northern Ohio, identified numerous outcrops of the Berea grit in northern central Ohio in Crawford, Morrow, and Delaware counties,[2] but probably did not find outcrops of the superjacent black shale, as it is not mentioned. There was no doubt in his mind regarding the identification of the Berea grit, as may be seen by the statement at the close of his account of the sections and the distribution of the formation in Delaware county, where he says:

> In general, the Berea grit in Delaware county is a very excellent stone for all purposes of building, and is very extensively quarried at Sunbury. It appears however, to be of a finer grain than in the northern part of the state, and the massive beds that characterize it in Lorain county are entirely wanting.[3]

Professor Winchell had studied the Berea grit at typical localities in the northern part of the state, and he correctly identified it as far south as near the southern line of Delaware county, in Harlem township. Had his correlation been accepted by later observers, the confusion which existed for several years regarding the correlation of the Waverly formations of northern and southern Ohio would have been obviated.

In 1875 Meek, in giving the horizon of *Discina* (*Orbiculoidea*) *Newberryi* Hall, stated that certain specimens came "from the Berea shale, a member of the Waverly group of the Lower Carboniferous,"[4] which is apparently the first usage of this name in a stratigraphical sense, although it does not clearly appear that Meek intended to recognize the shale as a stratigraphic unit.

In 1878, Dr. Orton published his *Report on the Geology of Franklin County*, in which it was stated that in the county the following divisions of the Waverly series arranged in ascending order are shown, viz., Waverly shales, ten to twenty feet; Waverly quarry system, sixty feet; and Cleveland shales fifteen feet.[1]

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[1] *Ibid.*, pp. 648, 649. [2] *Ibid.*, pp. 240, 259, 280. [3] *Ibid.*, p. 282.

[4] *Rept. Geol. Surv. Ohio*, Vol. II, Pt. II, "Palæontology," 1875, p. 278; also see statements in explanation of Plate XIV.

There was also reported a band of red or chocolate colored shale from fifteen to twenty feet in thickness at Taylor's Station, Jefferson township, and at several points in the eastern bank of Big Walnut Creek in Mifflin and Blendon townships,[2] which Dr. Orton considered the uppermost part of the Huron shale. This red shale, however, and the overlying Waverly shales represent the Bedford shale of Dr. Newberry's classification in northern Ohio. The Waverly quarry system is the Berea grit, although Dr. Orton in referring to Professor N. H. Winchell's report on Delaware county, in which outcrops at Sunbury and other localities in that county are correlated with the Berea grit, stated that "The Sunbury stone is erroneously referred in Vol. I [Vol. II], p. 282, to a higher division of the Waverly, viz., the Berea grit."[3] Finally, Dr. Orton stated, concerning the upper division of the Waverly as reported for Franklin county, that:

> The Cleveland shale of Dr. Newberry, the Waverly black shale of Professor Andrews, ... is known at but a single locality in the county, viz., at Ealy's Mills, in Jefferson township, on the banks of Rocky Fork. From ten to fifteen feet of this formation are here shown within the compass of an acre. The stone immediately underlying the black shale is quarried for local use, so that the line of junction is very distinctly seen at several points. The black shale lies upon the flat surface of the sandstone without the interposition of any other material whatever. A geological boundary cannot be more distinct than this. . . . . The surfaces of many slabs are thickly covered with the teeth and plates, and bones of the sharks and ganoids of this early day. Two brachiopods also, *Lingula melie* Hall, and *Discina Newberryi* Hall, are abundant here, sometimes wholly covering the surface of the beds. The anomalous but very interesting fossils termed *conodonts* are found in great numbers and in exquisite preservation in the shales of this locality.[4]

It is now known that the Cleveland shale is older than the Waverly black shale of Professor Andrews, and that the black shale on Rocky Fork is the continuation of the Berea shale of

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[1] *Rept. Geol. Surv. Ohio*, Vol. III, Pt. I, "Geology," p. 639.

[2] *Ibid.*, p. 638. [3] *Ibid.*, p. 642. [4] *Ibid.*, p. 642.

Meek, which is represented in the Ohio valley by the Waverly black shale of Andrews.

In July, 1878, Professor L. E. Hicks, of Denison University, published "the discovery that an unmistakable outcrop of Cleveland shale exists two miles east of Sunbury in Delaware county, southern [central] Ohio, on the land of Horace Whitney. It lies *above* the calcareous sandrock of the Sunbury quarries, which Professor N. H. Winchell, a special assistant on the Ohio Geological Survey, identified as *Berea grit.* My discovery *demonstrates* the incorrectness of that identification, and raises strong presumption, amounting almost to a certainty, that he was equally wrong in respect to his Berea grit in Morrow and Crawford counties."[1]

Professor Hicks was mistaken in this identification, and his conclusion regarding Professor Winchell's work was likewise erroneous; for the black shale which Hicks called the Cleveland is the Berea shale of Meek resting on top of the Berea sandstone, and therefore Professor Winchell's identification was correct.

In the September number of the same periodical, Professor Hicks named and described the divisions of "the Waverly group in central Ohio," or, "the strata lying between the Huron shales (Devonian) and the base of the Coal-measures," selecting "names derived from localities in Licking and Delaware counties."[2] In ascending order these names are (1) "Sunbury calciferous sandrock," 90 to 100 feet thick, which is the Berea grit; (2) "Sunbury black slate," from 10 to 15 feet in thickness, which is the Berea shale; (3) "Raccoon shales," 300 feet thick, a good exposure of which occurs on Moot's Run, a tributary of Raccoon Creek, four and one-half miles west of Granville, which are the equivalent of at least the lower and middle portions of the Cuyahoga shales of northern Ohio; (4) "Black Hand conglomerate and Granville beds," 85 to 90 feet thick; and (5) "Licking shales," from 100 to 150 feet thick.[3] In addition to the localities suggested by the names of these last two divisions the quarry beds of No. 4 are excellently shown in the Vogelmeier and Haven's quarries south of Newark and the Licking shales in "the gorge" to the southeast of Haven's quarry and Newark. These last two divisions of southern central Ohio were termed by Dr. Orton the Logan group.

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[1] *Am. Jour. Sci. and Arts*, 3d ser., Vol. XVI, p. 71.

[2] *Ibid.*, p. 216.

[3] *Ibid.*, p. 216.

In this paper Professor Hicks states:

> The Cleveland shale has been assumed by the Ohio geologists to be equivalent to the Waverly black slate, which is undoubtedly the same as that at Sunbury. At the time I discovered the outcrop at Sunbury I supposed there was no doubt of the correctness of this assumption. Now, however, Dr. Newberry asserts positively that there is *no evidence*, that they are identical.[1]

This is the first published statement, as far as the writer is informed, calling in question the correlation of the Waverly black slate of southern Ohio with the Cleveland shale of the northern part of the state; so it would appear that, as early as the summer of 1878, Dr. Newberry was aware of the mistake in his earlier correlation of these shales. Furthermore, Professor Hicks states that if Professor Winchell was correct in calling the Sunbury quarry stone the Berea grit, then "the chocolate shale described by President Orton as constituting the upper part of the Huron may be of the same age as the Bedford shales, as they were supposed to be by Dr. Newberry.[2] This appears to be the first published tentative identification of the Bedford shale in central Ohio, for in Dr. Newberry's account of the Carboniferous system, published in 1874, he stated:

> South of the Western Reserve the Bedford shales are scarcely distinguishable as in the central and southern portions of the state they assume the prevailing character of the Waverly group, and blend with the other portions of the series.[3]

The writer is not aware of any published opinion of Dr. Newberry's regarding the correlation of these red shales of Franklin county with the Bedford shale of northern Ohio.

In August of the following year, Dr. Orton published a

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[1] *Ibid.*, p. 221. [2] *Ibid.*, p. 221.

[3] *Rept. Geol. Surv. Ohio*, Vol. II, Pt. I, p. 92.

"Note on the Lower Waverly Strata of Ohio," in which the black shale of southern Ohio is for the first time correctly correlated with the black shale overlying the Berea grit in northern Ohio. Dr. Orton said:

> The identify of the Waverly black shale of southern Ohio and the Cleveland shale of northern Ohio, which was suggested as probable ten years since by Dr. Newberry, and which has since been adopted by most of those who have written on the geology of the Waverly group in Ohio, proves to be an error. . . . . The Waverly black shale finds its place directly above the Berea grit to the northward. The stratum has been distinctly described in the reports on the northern counties, but it has not been distinctly named. It has been treated of as the dark, fossiliferous shale at the base of the Cuyahoga shale. No better name could be found for it than Berea shale—for it makes the roof of the Berea quarries, just as it does of the lower Waverly quarries of Pike county.[1]

Dr. Orton made no reference to the paper of Professor Hicks of the preceding year in which he gave the name of Sunbury black slate to this formation in central Ohio; nor to Winchell's earlier correct identification of the Berea grit in central Ohio.

Dr. Orton gave a table correlating the Waverly formations of northern with those of southern Ohio. In this table the 75 feet of Bedford shale in the north is given as synchronous with the 90 feet of Waverly shale in the south; the 60 feet of Berea grit is equivalent to the 60 feet of the Waverly quarries and overlying blue shale; and the 10 feet of Berea shale is correlated with the 15 feet of Waverly black shale; while the 150 to 250 feet of Cuyahoga shale is represented by 300 to 400 feet of shale and sandstone in southern Ohio.[2]

In 1881, Dr. Orton read a paper before the American Association for the Advancement of Science, at Cincinnati, on "The Berea Grit of Ohio," in which he emphasized the fact that there is no serious difficulty in tracing the formation across the state, and again reviewed the correlation of the Waverly formations between northern and southern Ohio. In reviewing the earlier correlation he said:

> It will be observed that a comparatively thin bed of black shale occurs

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[1] *Am. Jour. Sci.*, 3d ser., 1879, Vol. XVIII, p. 138.

[2] *Ibid.*, p. 139.

in northern Ohio, overlain and underlain by blue shales, viz., the Cleveland shale, overlain by the Bedford and underlain by the Erie shale. A bed of black shale with similar boundaries has been noted in southern Ohio, viz., the Waverly black shale of Andrews. This latter stratum was assumed to be the true equivalent and extension of the Cleveland shale, and its fossils soon came to be credited to the latter. This identification placed the Berea grit of the north and the Buena Vista quarries of the Ohio valley on the same horizon.[1]

Dr. Orton stated that Professor N. H. Winchell first traced the Berea grit to central Ohio, as has already been shown in this paper; but he further said that "the Waverly quarry stone had been followed from the southward" to this part of the state, and "to abandon the preconceived error . . . . cost time and trouble." This, as far as the writer is aware, is the nearest published reference made by Dr. Orton to his classification of the Waverly rocks in the Franklin county report which has already been reviewed. Dr. Orton also reported that:

> The Waverly black shale of southern Ohio proves to be the black base of the Cuyahoga shale of northern Ohio, instead of the Cleveland shale, to which it was at first referred. The Waverly blue shale of southern Ohio is the Bedford shale of the north, like it also carrying enough peroxide of iron to redden it in many instances.[2]

In 1882, in discussing the source of the bituminous matter in the Devonian and Subcarboniferous black shales of Ohio, Dr. Orton wrote as follows:

> There are three strata of black shale in the Devonian and Subcarboniferous series of Ohio, viz., the Huron and the Cleveland shales of Newberry and the Waverly black shale of Andrews. The latter name I have followed Meek in replacing by the designation "Berea shale." It constitutes the base of the Cuyahoga shale of Newberry. . . . . The Berea shale, which directly overlies the Berea grit, ranges from 15 to 50 feet in thickness, and is separated from the great black shale [Ohio shale] by an interval of 100 to 150 feet, the interval being occupied by the Bedford shale and the Berea grit of Newberry. In northern Ohio the upper boundary of the Berea shale is not well defined. In central and southern Ohio it is sharp and distinct.[3]

In 1888, Dr. Orton described the Berea shale in his account of the "Geology of Ohio,"[1] but added nothing to what has already been cited, and this account was republished in 1893.[2]

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[1] *Proc. Am. Assoc. Adv. Sci.*, Vol. XXX, 1882, p. 170.

[2] *Ibid.*, p. 171.

[3] *Am. Jour. Sci.*, 3d ser., Vol. XXIV, p. 171.

Professor Cushing reported the Berea shale in northeastern Ohio, with a thickness of 40 feet overlying 35 feet of Berea grit, near the Pennsylvania line, and farther west in his section through Warren, Trumbull county, 55 feet of Berea shale.[3]

For some years Professor C. L. Herrick studied the Waverly series, and in his general conclusions introduced the term "Berea" or "Transition series," which included the rocks from the base of the Cleveland shale to either the bottom or top of a conglomerate in the upper part of the Waverly, which he called conglomerate I.[4] It is not clear whether this conglomerate was included in the Berea series or not, for on page 100 it is given in this series, but on page 105 it is given in the overlying Kinderhook division. One of the divisions of the Berea series he called the Berea shale, but included in it not only the black shale which Dr. Orton called the Berea, but also the greater part of the overlying Cuyahoga shale as defined by Dr. Orton. The upper 40 feet of shale in the Berea series underlying conglomerate No. 1 was called the Waverly shale.[5]

In a later paper, however, Professor Herrick was not inclined to extend the limits of the Berea shale beyond those of Dr. Orton, for he wrote as follows, under the heading "Berea Shale":

> This term is conveniently applied to the thin band of bituminous shale above the [Berea] grit and perhaps should not be extended (as the writer has done in a previous paper) to the gray and blue shales above. In southern Ohio it varies from fifteen to twenty feet in thickness and is little more than two feet thick at Chagrin Falls.[6]

Mr. W. F. Cooper, who continued the investigation of Professor Herrick on the Waverly series, used the term "Berea shale" in the sense in which it was first used by Professor Herrick; but made two divisions, viz., first, the lower Berea shale, resting on the Berea grit, 180 feet (?) in thickness, capped by the upper Berea shale, 30 feet thick, which was described as "the most fossiliferous zone yet found in the Waverly of Central Ohio."[1] Later, however, Mr. Cooper used the term "Berea shale" in the sense in which it was used by Dr. Orton, for he wrote as follows:

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[1] *Rep. Geol. Surv. Ohio*, Vol. VI, pp. 36, 37.

[2] *Ibid.*, Vol. VII, p. 30.

[3] *Proc. Am. Assoc. Adv. Sci.*, Vol. XXXVI, 1888, p. 214.

[4] *Bull. Denison Univ.*, Vol. IV, 1888.

[5] *Ibid.*, pp. 106, 107.

[6] *Bull. Geol. Soc. Amer.*, Vol. II, Jan. 1891, p. 35.

> The Berea shale is immediately over the Berea sandstone. . . . . This horizon has also been called the Waverly black shale, by Andrews, varies in Ohio from 15 to 50 feet in thickness, throughout the line of outcrop, and is an exceedingly persistent and well defined horizon.[2]

In 1889, Dr. Newberry gave the thickness of the Waverly group in northeastern Ohio as about 500 feet, which he stated was composed of the following divisions :[3]

	Average thickness.
1. Cuyahoga shale - - - - - -	230 feet
2. Berea Shale - - - - - - -	20
3. Berea Grit - - - - - - -	60
4. Bedford Shale - - - - - - -	75
5. Cleveland Shale - - - - - -	50

He also referred to Professor Hicks' announcement of the discovery of the Cleveland shale in Delaware county, and stated that:

> I think he has found there the Berea shale, which lies immediately above the Berea grit. This latter shale is persistent southward, and is apparently the black shale, so rich in fish remains at Vanceburgh, Kentucky. I suspect the Cleveland shale does not pass south of the line of the Western Reserve.[4]

The above clearly shows that Dr. Newberry abandoned his early idea of the extension of the Cleveland shale across the state, and accepted the later correlation of the Berea shale of northern with the Waverly black shale of southern Ohio.

DISTRIBUTION.

CENTRAL OHIO.

Rattlesnake Creek near Sunbury.—In this account of the distribution of the Sunbury shale across the state we will begin with the locality in central Ohio, which has furnished its name, and then describe some of the more important outcrops from there south to northern Kentucky. Returning to Sunbury, its outcrop will then be traced to the north and east nearly to the Pennsylvania line.

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[1] *Bull. Sci. Lab. Denison Univ.*, Vol. V, 1890, pp. 25, 26.

[2] *Geol. Surv. Michigan*, Vol. VII, Pt. II, 1900, p. 286.

[3] *Monographs U. S. Geol. Surv.*, Vol. XVI, "The Palæozoic Fishes of North America," p. 120.

[4] *Ibid.*, p. 129.

The Sunbury shale was named by Professor Hicks in 1878, from exposures on Rattlesnake Creek, on the present farm of Amasa Whitney, about two miles east of Sunbury, Delaware county.[1] If an opportunity remained to select a place for the name of the formation, a much more conspicuous outcrop might be found, but as this has been regularly defined and published it is the writer's opinion that Sunbury shale should be accepted. Professor Hicks described the formation as "a black, bituminous shale containing shells of *Lingula* and *Discina* and spines, scales, and teeth of fishes. But one outcrop of it is known in Delaware county, and that was revealed only by a systematic search of a day and a half."[2] Some three and one-half feet of this shale is shown on the northern bank of Rattlesnake Creek a short distance north of the house of Amasa Whitney. As exposed it is black and argillaceous, rather rotten from weathering, greatly iron-stained between the layers with some lighter colored blotches, and contains iron pyrites. Below this outcrop, at irregular intervals, there are several exposures of the shale on the bank of the creek, and in a loose piece a specimen of a fairly large *Lingula* was found, which was the only fossil secured at this locality. The lower part of the shale, however, in which fossils are generally the most abundant, is not shown here, and the top of the Berea grit forms the bed of the creek a little below the house of Mr. W. P. Swallow. The upper layer of the Berea is greatly iron-stained, contains considerable iron pyrites, and has quite an irregular surface.

A little further down the stream is an outcrop on the southern bank where between two and three feet of thin bedded sandstone is shown. It is buff to bluish-gray in color, much of it quite iron stained, of fairly fine grain and somewhat friable. There is no question but that these outcrops just below the house of Mr. Swallow are in the very upper part of the Berea grit.

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[1] *Am. Jour. Sci.*, 3d ser., Vol. XVI, pp. 216, 219, 220. Also see p. 71 for a further account of the locality.

[2] *Ibid.*, pp. 219, 220.

Rocky Fork.—Dr. Orton noted "an outcrop of black shale on the farm of Lorenzo Taylor, Esq., of Plain township," in the northeastern part of Franklin county, which he stated "may prove to belong to the Cleveland shale."[1] This outcrop has not been seen by the writer, but it is probably in the Sunbury shale, since it is situated about in the line of strike of this formation.

The best exposure of the Sunbury shale in central Ohio is on the banks of Rocky Fork, in Jefferson township, in the eastern part of Franklin county, 2.3 miles northeast of Gahanna. It is well shown on the banks of the creek, both below and above the highway bridge, on the David S. Stagg farm. The first high bank on the eastern side of the creek below the bridge gives a fine exposure of the middle and upper part of the Berea grit, capped by the lower half of the Sunbury shale. The section of this bank is as follows, and it is shown in Fig. 1.

ROCKY FORK SECTION.

No.		Thickness feet.	Total thickness feet.
6.	Soil and drift	7	37
5.	*Sunbury* black argillaceous shale, capping the Berea grit, the contact of which is finely shown on the vertical bank. About 8 inches above the base of the shale is a zone of fossils in which *Lingula melie* Hall was obtained	7	30
4.	Thick stratum of light gray sandstone forming the upper part of the *Berea grit*	6¾	23
3.	Parting of shaly sandstone to shales	....	....
2.	Zone of light gray to bluish-gray sandsone, somewhat irregularly bedded, and lenticular with some shale partings	12	16¼
1.	Shaly sandstone alternating with layers of shale, Berea grit to creek level.	4¼	4¼

The lower two or three feet of Sunbury shale capping the Berea grit is also shown on the western bank of the creek somewhat above the cliff just described; while at various places on the bank and in the bed of the creek are magnificent examples of ripple marks in the fairly thin layers of Berea sandstone.

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[1] *Geol. Surv. Ohio*, Vol. III, p. 643.

Just above the highway bridge is an old quarry in the upper part of the Berea grit, some of the layers of which are bluish in color. Capping the sandstone is the lower two feet or more of the black argillaceous Sunbury shale, and at this locality the clearly shown contact of the two formations may be closely examined. The black shale splits into thin layers, and one of these, a few inches above its base, contains abundant specimens of *Lingula melie* Hall and *Orbiculoidea Newberryi* (Hall), Herrick,[1] together with fragments of fish bones and teeth. Farther up the creek, on the same bank, 8 feet or more of the shale is shown.

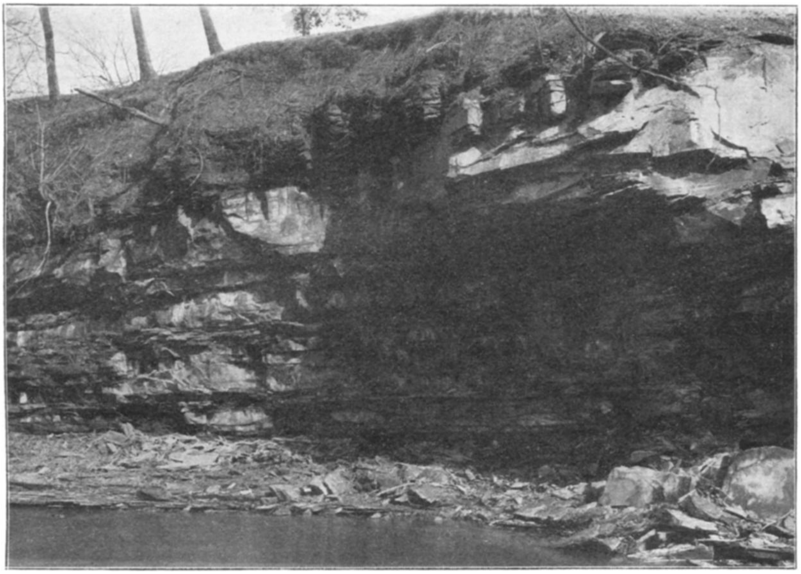

FIG. 1.— Contact of Berea sandstone and Sunbury shale on Rocky Fork, two miles northeast of Gahanna. The thin bedded Sunbury shale is shown in the upper part of the cliff resting on a thick sandstone layer at the top of the Berea.

On the eastern bank of the creek, not far above the highway bridge is a rock cliff, the lower 5½ feet of which, to the creek level, is the upper part of the Berea grit, while above is 7± feet of the Sunbury shale capped by drift and soil. The contact of the Sunbury shale and Berea grit is also nicely shown in this outcrop.

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[1] Mr. Schuchert refers this species to Whitfield's genus of *Lingulodiscina* (*Bull. U. S. Geol. Surv.*, No. 87, p. 261).

At this place was formerly a mill known as Ealy's, and this is the locality which was said by Dr. Orton to be the only one in Franklin county where the Cleveland shale of Dr. Newberry or the Waverly black shale of Professor Andrews was known. He stated that "from ten to fifteen feet of this formation are here shown within the compass of an acre."[1]

Some difficulty was experienced in obtaining the thickness of the Berea grit at this locality, and in a former paper the writer has given it as "about 40 feet."[2] South of the bridge, however, the first steep bank on the eastern side of the creek below the one which furnished the above section, apparently gives the base of the Berea grit, and unquestionably its top, so that we probably have the entire thickness of the formation given in this nearly vertical cliff. The Sunbury shale on the bank a little back of the edge of the cliff had not been noticed when the former paper appeared, although the apparent contact of the Berea grit and Bedford shale near the base of the bank was observed. The section of this bank is as follows:

No.		Thickness feet.	Total Thickness feet.
3.	Black argillaceous shale in thin layers; the base of the *Sunbury shale* - - - - - - - - - - - - -	3	39½
2.	*Berea grit*, the upper part of which consists of fairly massive sandstones, the layers a foot or more in thickness, while the basal part is composed of thin bedded sandstones, and all through the formation shale partings occur at irregular intervals. Below these thin bedded sandstones are grayish shales, so that the entire formation is apparently shown between these two shales - - - - - - - - - - - - - -	33½	36½
1.	Grayish to bluish-gray, somewhat arenaceous shales to the creek level, which are considered as at the top of the *Bedford shale*.[3]	3	3

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[1] *Geol. Surv. Ohio.* Vol. III, p. 642. [2] JOUR. GEOL., Vol. IX, 1901, p. 218.

[3] As is well known "Bedford oölitic limestone" has been used as the name of a Subcarboniferous formation in Indiana. The question has arisen whether Bedford

On the western bank of the creek, at the first cliff below the one just described, is a concretionary sandstone, the layer about 1 foot 8 inches in thickness, below which are grayish shales partly covered to the creek level. Above the concretionary sandstone are 7 feet 8 inches of shales, which are mainly argillaceous but become arenaceous at the top. These shales are succeeded by thin bedded sandstones, which are thicker above, showing at one place a conspicuous concretionary layer, and these sandstones are clearly in the Berea. When traced up the creek, however, the lower concretionary sandstone is apparently near the horizon regarded as the base of the Berea in the preceding section, and it is therefore thought to correspond more nearly with the base of the formation than the higher thin bedded sandstones. If this be accepted, however, as the base of the Berea, then there is 7⅔ feet of shale included in the lower part of the formation. In the short distance between these two cliffs a rapid change in lithologic character is indicated and the lower limit of the formation must therefore be regarded as a rather variable line.

Somewhat below this bank is a bend in the creek, where a steep cliff with a conspicuous tree near its edge is shown on the same side of the creek. At this locality the upper part of the Bedford shale is finely shown, as well as the transition into the Berea grit. The section is as follows:

should be retained as the name for the Indiana or Ohio formation, and both views have been pretty fully given in the JOURNAL OF GEOLOGY (see Vol. IX, April–May, pp. 215, 232–36, 267–72). Later the writer referred the matter to the committee on geologic names of the United States Geological Survey, which has been organized for the consideration of similar questions in geologic classification and nomenclature, and the following decision has been communicated by the director, Hon. Charles D. Walcott: "(1) That Bedford rock was used by Owen in 1862 in a *Report of Geological Reconnaissance of Indiana*, 1859–60, p. 137, but the usage is so indefinite as not to constitute a preëmption of the term for stratigraphic purposes. (2) Bedford shale is a term first employed by Newberry in *Ohio Geological Survey Report of Progress*, 1869, p. 29, and this usage should stand. Furthermore, it is understood here that Mr. Cumings has recently proposed to drop the name of Bedford limestone of Indiana, and substitute for it Salem limestone."

No.		Thickness feet.	Total thickness feet.
6.	Soil and drift	6	56½
5.	Grayish sandstone layers, about 1 foot thick, but with some shaly partings. *Berea grit*	13	50½
4.	Arenaceous shales	4	37½
3.	Argillaceous shales	6½	33½
2.	A concretionary layer of sandstone, which is thought to represent the base of the *Berea grit*	1±	27
1.	Argillaceous shales to the creek level; in the lower part are reddish-gray spots which give them a slightly mottled appearance, *Bedford shale*[1]	26	26

In the above section the concretionary sandstone — No. 2 — is regarded as marking the base of the Berea grit instead of the higher sandstones of No. 5, because No. 2 is thought to represent the concretionary sandstone noted on the bank farther up the creek, which was determined by level to correspond approximately with the base of the sandstones on the other side of the creek, where the entire formation is shown.

In the deeply drift-covered eastern part of Franklin county, which is also true of Fairfield county on the east and Pickaway county to the south, there are but few outcrops of the Sunbury shale. Dr. Orton noted its occurrence at one locality in Fairfield county, and his statement was that "it undoubtedly exists in Pickaway and Fairfield counties, though its presence has not been determined in either, except at a point just beyond the Franklin county line, to the south of Canal Winchester."[2]

SOUTHERN OHIO.

Benner's Hill. — In southern Ohio, in Ross, Pike, Scioto, and Adams counties, are numerous outcrops of the Sunbury shale, and its distribution may be readily traced across that portion of the state. In this paper only a few of these outcrops will be described, and they have been selected at some distance from each other in order to fairly represent the character of the formation across the southern part of the state.

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[1] An earlier interpretation of this section was given in the JOURNAL OF GEOLOGY, Vol. IX, p. 217.

[2] *Geol. Surv. Ohio*, Vol. III, p. 643.

One of the most interesting sections of the Devonian and Subcarboniferous formations of southern Ohio is that of Benner's Hill, about two miles northwest of Bainbridge, in the southwestern part of Ross county. The section begins on the eastern bank of Buckskin Creek, a short distance below the railroad bridge and house of Mr. George Walley, and follows the steep part of the hill to the bare spot of shale known as Bald Knob, and then runs through the woods to the Walley sandstone quarry and top of the hill.

BENNER'S HILL SECTION.

No.		Thickness feet.	Total thickness feet.
7.	Covered to the highway directly east of the quarry, which crosses about the highest part of that portion of the hill. Loose by the roadside is brownish-red shale, which is apparently from near that horizon. The greater part of this covered slope belongs in the *Cuyahoga shale*	36	490
6.	Black fissile bituminous shale vertical wall of 9 feet on top of the quarry sandstone. *Sunbury shale*, formerly known as the Waverly black slate. The contact between the black shale and the subjacent Berea sandstone is beautifully shown on the vertical wall of the George Walley quarry. The contact is sharp and it makes a conspicuous line	9	454
5.	The upper 7 feet is a massive sandstone layer, which in places does not split into layers. The upper 18 feet of the formation is composed of very massive light gray, generally rather coarse-grained sandstone, with few bedding planes. Below is 13 feet composed of sandstones, the layers of which vary in thickness from 1 to 2½ feet, and alternate with shales. The color varies from bluish to buff and numerous layers of the sandstones in the lower part of the quarry show excellent examples of ripple marks. At the base, sandstones 6 inches or more in thickness alternate with shales; but this portion is partly covered, and a clear line of contact between the sandstones and the underlying Bedford shale is not shown. These sandstones represent the *Berea grit*, and were formerly called the Waverly quarry system	33	445
4.	The interval of the *Bedford shale* is mostly covered; but at the base, near the line of springs, are brownish to buff arenaceous shales. The barometer gave 63 feet for the interval, which is perhaps greater than the actual thickness, since Dr. Orton gave it as 50 feet.[1] This formation was formerly known as the Waverly shales	63	412

[1] *Geol. Surv. Ohio*, Vol. II, p. 645.

3. Probable top of the Ohio shale as indicated by the line of springs, but the upper 7 feet is covered. From the bare summit of Bald Knob to base of shales, 325 feet, nearly all of which is shown by following the run on the lower part of the hill and higher, on its steep western face. The rocks are thin black fissile shales, weathering to a somewhat lighter color, and some of the pieces contain large numbers of *Protosalvinia huronensis* Dawson. The lower 13 feet, as shown in the highway cutting near the base of the hill, is a thin, light buff fissile shale, which weathers to a much lighter color than the shale above, and the weathered pieces are often stained red from iron. Dr. Orton stated that the base of the series was composed of "26 feet of white and blue clays."[1] All of this division is referred to the *Ohio shale*, which in Dr. Orton's section is called the Huron shales,[2] but they probably represent the Huron, Erie, and Cleveland shales of northern Ohio. The thickness of 332 feet is the same in the two sections - - - - 332 349

This formation was named the Ohio black slate by Andrews in 1870, and described as extending from the "Ohio river hills in the vicinity of Rockville, Adams county," northward to the hills at Chillicothe, spreading itself across the upper part of the Scioto valley and "resting upon the Corniferous limestone in the vicinity of Columbus."[3] In 1879 Professor Lesley applied the term Ohio conglomerate to the one occurring at the base of the Pennsylvanian or Carboniferous series in Ohio, stating that the Sharon conglomerate "is undoubtedly part (or the whole) of the *Ohio conglomerate*."[4] While in 1894, Mr. George H. Eldridge apparently named a Cretaceous formation in central Colorado, the Ohio formation evidently, from exposures on both sides of the Ohio creek in the southeastern part of the Anthracite quadrangle.[5] Of course both of these names are clearly synonyms of Andrews's "Ohio black slate," which in later years has generally been shortened to Ohio shale.

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[1] *Ibid.*, p. 646. [2] *Ibid.*, p. 645.

[3] *Geol. Surv. Ohio,* "Pt. II, Rept. of Progress in the Second Dist.," p. 62.

[4] *Second Geol. Surv. Pa.*. Q^2, 1879 (?), Preface, p. 34, and see p. 29. Also see Q^3, 1880, pp. 56 f., 45 f.

[5] *Geological Atlas U. S.*, Folio 9—Anthracite-Crested Butte Folio, pp. 6, 7. In the legend of the geologic sheets, save one, it is called "Ohio creek formation;" but in the text and on the "Columnar section" the name is given as "Ohio formation."

2. Partly covered slope below the highway; but there are some thin projecting pieces of limestone. This zone probably represents the *Waterlime* or *Lower Helderberg*; but on account of scanty outcrops its correlation was not definitely settled. Above the railroad bridge the Waterlime is quite well exposed on the bank, between the railroad track and the highway. The rock is of a drab color, and some of the weathered layers are very rough. Part of the layers are quite sandy, and some of them are a form of breccia. Fossils occur; *Leperditia* is quite common in some of the layers, a few specimens of *Streptorhynchus hydraulicum* Whitf. were found, and a fairly large Gastropod shell - - - - - - - - - - - - - -	6	17
1. Massive light gray to drab limestone on the banks of Buckskin Creek to water level. A section of a shell, apparently *Pentamerus*, was found, while on the opposite bank of the creek above the railroad bridge imperfect impressions of shells, apparently *Megalomus*, were seen, so that this zone probably belongs in the upper part of the *Niagara limestone* - - - - - -	11	11

This section was briefly described by Dr. Orton,[1] the total thickness of which he made 500 feet, while in the above section it is 490 feet. He gave the thickness of the Niagara and Helderberg (Waterlime) limestones at the base of the hill as *each* 15 feet in thickness, which is some 10 or 12 feet greater than it can possibly be at this locality. Dr. Orton gave the Huron shales as 332 feet in thickness, the Waverly shales as 50 feet, the Waverly quarry courses as 31 feet, the Waverly black slate as 15 feet, which is probably nearer the actual thickness of the formation than the statement in the above section; still, as a matter of fact, but 9 feet are shown in the quarry, and for the upper beds of Waverly group 42 feet, but it is true that beyond the highway the hill is somewhat higher than at the point where my section terminated. A diagrammatic section of this hill is given in accompanying figure (Benner's Hill Section).

Stony Creek.—The Benner's Hill section is near the western line of Ross county, and the other outcrop in this county selected for consideration is one in the Scioto valley in its southeastern part. Stony Creek is a western tributary of the Scioto river, which it enters near the middle point of the eastern line of Franklin township.

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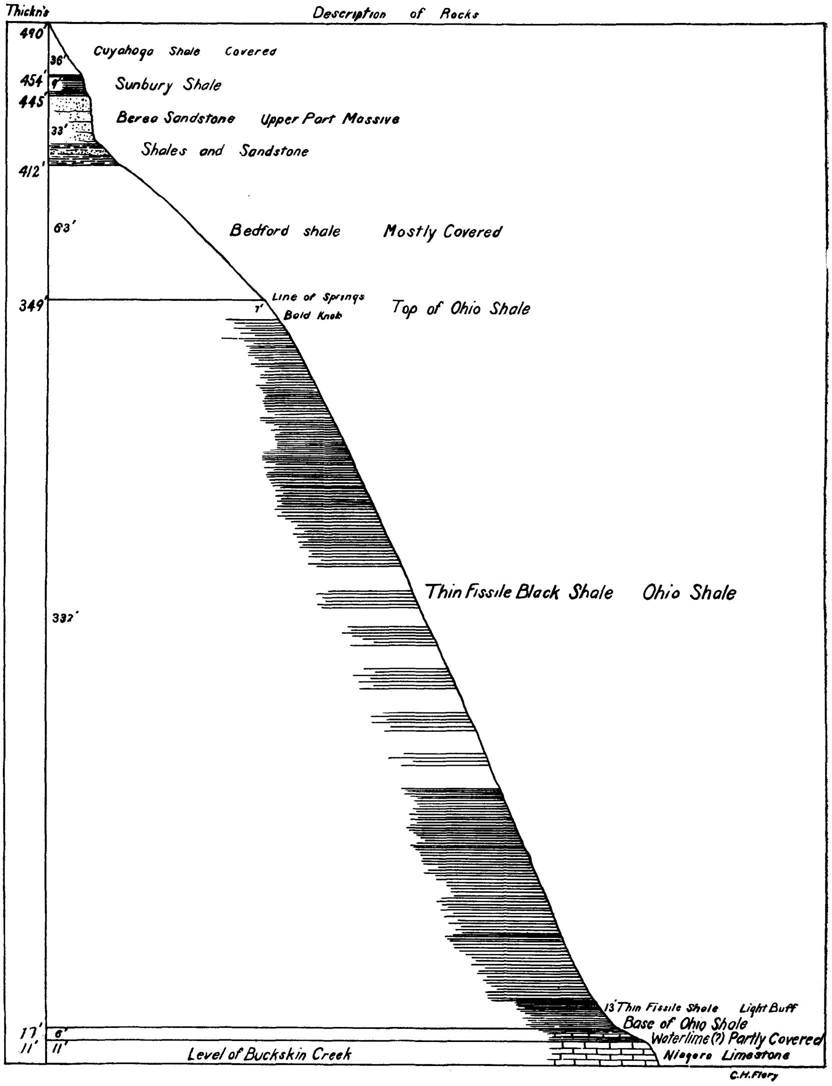
[1] *Ibid.*, p. 645.

BENNER'S HILL SECTION



The Canal pike crosses Stony Creek at a point eight miles southeast of Chillicothe and eleven miles northeast of Waverly. A short distance below this highway bridge the viaduct of the Norfolk & Western Railroad crosses the creek, and on its southern bank a few rods above the viaduct is an interesting

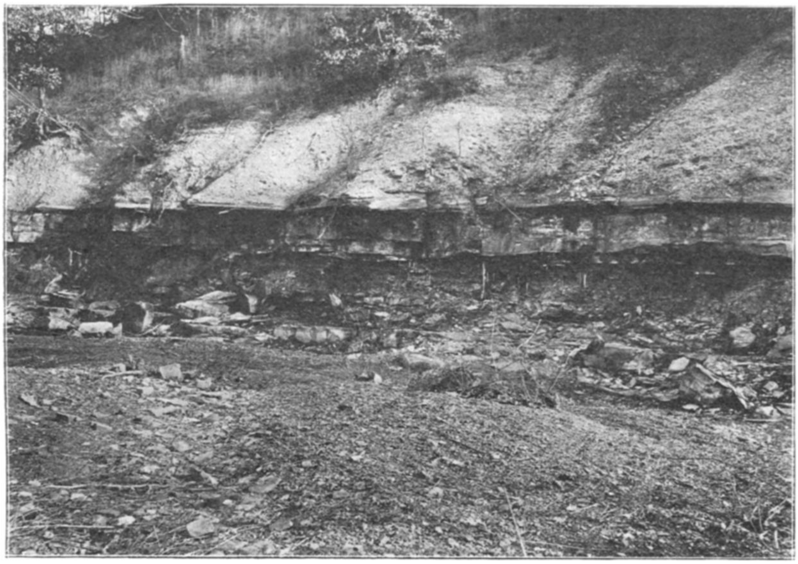


FIG. 2.—Contact of Berea grit and Sunbury shale on Stony Creek, Ross county. The thin, even layers of shale at the base of the Sunbury project beyond the Berea grit.

outcrop of the Sunbury shale, Fig. 2. The following section of the bank was made at this locality:

STONY CREEK SECTION.

No.		Thickness feet.	Total thickness feet.
4.	A projecting ledge of thin bedded brownish sandstone occurs below the highway; the remaining portion of the bank covered to the road - - - - - - - - - - - - -	¼	45+
3.	All thin black shale, in no particular respect differing from the Sunbury shale of central and northern Ohio. This outcrop forms the middle part of the bank just below the highway as it goes over the ridge south of the N. & W. viaduct. The *Sunbury shale*		

	with one of the thickest outcrops known in the state. The black shale is also shown by the side of the highway above the cliff as it descends the slope to the northwest	28—	45
2.	Massive sandstone, brown on weathered edge, with a thickness of 1 foot 8 inches. Then thin sandstone at top, olive shales in middle, and thin sandstone at the base, with a total thickness of 1 foot 5 inches. At the bottom a massive, fine-grained sandstone, 1½ feet thick. The total thickness of this zone is 4 feet 7 inches, and it was regarded by Dr. Orton as representing the Waverly quarry courses[1] or *Berea grit.* If this correlation be true, then there is to be noted a remarkable thinning in the formation when compared with the Benner's Hill section or the quarries in the vicinity of Waverly	4½+	17
1.	Bluish to bluish-gray shales, with thin layers of sandstone, to the creek level. Some of the layers of sandstone show fine examples of ripple marks, and one layer about 5½ feet above the base has a thickness of 6 inches. This zone was referred to the Waverly shales by Dr. Orton, who stated that "the uppermost 25 feet of the Waverly shales appear here."[2] The base of this section is at the creek level on the upper side of the viaduct, which is hardly more than 4 feet above the level of the Scioto river, so there is scarcely any opportunity for an exposure of 25 feet of these shales at this locality. It is not improbable if the rocks were exposed to a greater depth at this point that thicker sandstones would be shown and all this lower part of the section might be referred to the *Berea grit.* The thin sandstones with beautiful ripple marks rather support this inference, since similar ripple marks occur so generally in the lower part of this formation and not in the upper part of the Bedford shale	12½	12½

This section was briefly described by Dr. Orton, who reported "twenty-seven feet of the Waverly black slate, the heaviest section of this stratum yet reported in southern Ohio,"[3] which is practically the same as that obtained by the writer.

The bluish-gray shales with thin alternating sandstones are exposed on the banks of the creek above and below the highway bridge, while the lower massive stratum of the Berea grit is shown at the top of the bank immediately east of the bridge.

Another section was measured on the south bank of Stony

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[1] *Ibid.*, p. 650.

[2] *Ibid.*, p. 650.

[3] *Ibid.*, p. 650; also see p. 624, where it is stated that this is "the best section of it to be found in all the Scioto valley."

Creek, about one-half mile above the former, on the Wolf farm, which is as follows:

No.		Thickness feet.	Total thickness feet.
7.	At least 18 feet of thin even black shale is shown; the upper part of which is much weathered and broken and finally concealed by soil. The thin, even layers of the lower part are finely exposed, and there is a sharp and clearly shown line of contact between the shale and the underlying sandstone. *Sunbury shale*	18	29½
6.	Massive rather fine-grained bluish-gray sandstone, at top of *Berea grit*, which has a tendency to split into irregular layers, and in places there are shaly partings. Base of heavy stratum	$3\frac{7}{12}$	11½
5.	Blue to bluish-gray arenaceous shales and thin sandstones	3⅙	$7\frac{11}{12}$
4.	Blue sandstone stratum of variable thickness	½±	4¾
3.	Bluish arenaceous shales and thin sandstones	1¾	4¼
2.	Bluish-gray compact sandstone, which is sometimes concretionary and of somewhat variable thickness	1½	2½
1.	Bluish shales and thin sandstone to bed of creek; the sandstone very much ripple marked	1+	1

It appears to the writer that the first six numbers of the above section may be referred to the Berea grit instead of simply the massive 3½ feet of sandstone—No. 6—immediately below the Sunbury shale. It is true that a considerable part of the rocks below No. 6 are shales; but the sandstones are thicker than in the first section, and this extreme development of shales on Stony Creek is thought to be simply a local phase of the formation. The above section is shown in Fig. —, where the massive 3½ feet of sandstone at the top of the Berea forms a conspicuous layer across the middle part of the halftone, just above which is seen the projecting layer of thin, even-bedded black shale at the base of the Sunbury.

On the east fork of Stony Creek, about one mile above Wolf bank, are ledges of rather bluish-gray sandstone alternating with layers of thin sandstones, which are ripple marked. This is an outcrop of the *Berea grit*, and in the field to the west, and somewhat higher, are the thin black *Sunbury shales.*

Waverly.—The rocks of the Waverly series were named from outcrops in the vicinity of Waverly, to which Professor C. Briggs, Jr., in 1838, gave the name *Waverly sandstone series*,[1] to the rocks occurring between the "argillaceous slaty rock, or shale stratum," now known as the Ohio shale, and the "conglomerate" which lies at the base of the Coal-measures.

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[1] *First Ann. Rept. Geol. Surv. Ohio*, p. 80.

In Dr. Orton's description of the geology of Pike county, he termed the shales between the top of the Ohio black slate and the base of the higher massive sandstones the *Waverly shales*,[1] a name apparently proposed by him; while the sandstone which is now known to be the continuation of the Berea of northern Ohio, was named the *Waverly quarry system*.[2]

The old Waverly quarries, formerly operated by Emmett, were mainly on the road toward Pee Pee, and are no longer actively worked. The same sandstone, however, is now quarried along the line of the Ohio Southern railroad up to the Crooked Creek valley to the northwest of Waverly. One of the nearest quarries to Waverly is that of the Southern Ohio Stone Co., on the Ohio Southern railroad, 1 ½ miles above the Waverly station, or about 2 miles up the Farmersville pike, northwest of Waverly. This quarry has been open some seventeen years, and for a time was worked by the railroad company. The detailed section of the Berea sandstone in this quarry is given below.

SECTION OF THE SOUTHERN OHIO STONE COMPANY QUARRY.

No.		Thickness feet.	Total thickness feet.
14.	*Sunbury black shale*, 2 feet shown in pit above the top of the quarry - - - - - - - - - - - - - -	2	65
13.	Covered interval of 1 foot 2 inches - - - - - - -	1⅙	63
12.	Thin-bedded sandstone at the top of the *Berea sandstone* - -	2	61 ⅚
11.	Rather thin sandstone on quarry face, but thickens under cover, and will make quarry stone - - - - - - - - -	5	59 ⅚
10.	Bridge stone, 22-inch stratum - - - - - - - - -	1 ⅚	54 ⅚
9.	Shaly to thin-bedded sandstone - - - - - - - -	3	53
8.	Good sandstone in three layers, upper course 12 inches, middle one 18 inches, lower 15 inches - - - - - - -	3¾	50
7.	Shaly sandstone - - - - - - - - - - - - -	$1\frac{5}{12}$	46¼
6.	Good sandstone -- - - - - - - - - - - - -	1 ⅚	44 ⅚
5.	Shaly layers to thin-bedded sandstone; but the greater part of the stratum is concretionary with some shale — the "bowlder layer" of the quarry men - - - - - - - - -	6	43

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[1] *Rept. Geol. Surv. Ohio*, Vol. II, Pt. I, 1874, p. 619.

[2] *Ibid.*, p. 621.

4.	The best stone in the quarry, which is sawed and shipped extensively; the upper course 16 inches and the lower one from 18 to 20 inches in thickness. Base of quarry	3—	37—
3.	Course of 32 inches	2⅔	34
2.	Good sandstone, which is apparently the base of the *Berea sandstone*	1⅓	31⅓
1.	From base of the Berea sandstone covered slope to mouth of well directly below quarry at house of Mr. L. S. Risley. According to Mr. Combs, the top of the Ohio black shale was struck at a depth of from 30 to 40 feet in this well, which gives a thickness from 60 to 70 feet for the Bedford (Waverly) shale. Dr. Orton gave the thickness of the Waverly shales in Pike and Ross counties as 90 feet[1] and it is not improbable that the top of the Ohio black shale occurs at a greater depth in the well than reported above	30	30

The above section gives nearly 32 feet for the thickness of the Berea sandstone, and 60 to 70 feet for that of the subjacent Bedford shale. The general color of the building stone is gray, although sometimes rather buff or even greenish on weathered surface. There are layers showing ripple marks and also bluish to greenish shales, some of which are much iron stained. The general appearance of the stone is quite similar to that of the Berea sandstone in central Ohio.

The slope of the hill above the sandstone is very gradual, and the Sunbury or Waverly black shale does not make conspicuous outcrops; but its occurrence immediately above the sandstone is shown in the small pit above the quarry, where two feet of its lower part is exposed.

On the "General section of the Waverly system in Pike and Ross counties"[2] Dr. Orton gave, as occurring between the Waverly quarries and the Waverly black slate, a zone of "shales with concretions of iron ore" 30 feet in thickness. This zone is apparently not described in the text, where it is stated that the Waverly black slate comes "immediately above the Waverly quarries,"[3] and no indication of this intermediate shale was seen in the sections which were examined by the writer.

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[1] *Rept. Geol. Surv. Ohio*, Vol. II, Pt. I, 1874, Fig. 1, op. p. 615, and Fig. 2, op. p. 618.

[2] *Ibid.*, Fig. 1, op. p. 615, and Fig. 2, op. p. 618.

[3] *Ibid.*, p. 624.

About 1½ miles farther up the railroad, at Peck, are the extensive quarry and mill of the Waverly Stone Co., which also obtains its stone from the Berea sandstone. There is also a small quarry located on the eastern side of the valley, called Peck's quarry.

Mr. I. Combs, the superintendent of the Southern Ohio Stone Co. has not seen the Waverly brown sandstone, which occurs near the base of the Cuyahoga shales, overlying the Sunbury shale, in the hills bordering Crooked Creek; but the locality east of the river, where it caps the hill on the Gregg farm, is well known to him. He also reported excellent outcrops of it farther north on the eastern side of the river, about one mile below the Omega river bridge. Dr. Orton reported this sandstone as 10 feet in thickness on his section of the "Waverly System in Pike and Ross counties" with 35 feet of blue shales between it and the top of the Waverly [Sunbury] black slate.[1] He correlated it with the stone obtained high in the bluffs on the northern side of the Ohio river near Buena Vista and called it the Buena Vista stone,[2] which correlation is restated in his last account of the geological scale of Ohio.[3]

Buena Vista.—The extensive quarries near the head of an east branch of Lower Twin Creek, some five miles northwest of Beuna Vista, were studied. A tramway extends from the town to the quarries, and a highway may be followed to No. 4 on the tramway, within about one mile of the older quarries, which are no longer worked. On the bank of the creek, just above No. 5 of the tramway, is a good exposure of the upper part of the Ohio shale, which begins at creek level and extends up the bank for 24 feet, when the shales are covered by soil. Two species of *Lingula* were found near the top of these shales, the most common one resembling quite closely *Lingula Williamsana* Girty, while a larger species is also found lower in the bank. A sandstone ledge in the lower part of the Bedford is shown not much farther up the bank.

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[1] *Ibid.*, Fig. 1, op. p. 615, and Fig. 2, op. p. 618.

[2] *Ibid.*, Fig. 1, op. p. 615, Fig. 2, op. p. 618, and p. 626.

[3] *Ibid.*, Vol. VII, 1893, p. 31.

On the eastern side of the creek at this locality is an old incline, at the top of which is an unworked quarry. The lower part of this quarry shows the thin, black, laminated Sunbury shale, the loose pieces of which are conspicuous on the dump near the top of the bluff, as seen from the creek valley below. Above the Sunbury is olive-colored shale, capped by the Buena Vista quarry stone, in two layers, or "City ledge" as the outcrops of this stratum near Rockville, between one and two miles below Buena Vista, were termed in 1838 by Professor John Locke, in his geological account of Adams county.[1]

Some distance up the tramway from No. 5 is the incline in present use, the foot of which is barometrically 130 feet below the base of the "City ledge" at its top. Perhaps 15 to 20 feet above its base are fairly heavy sandstone layers in the Bedford formation, which, in the Ohio river bluffs, contains much more sandstone than in the central part of the state. The Berea sandstone is shown at the side of the incline near its top, where the top of the formation is marked by a massive stratum, 1 foot 9 inches in thickness, below which are thinner bedded and shaly layers. The Berea is light gray in color and fairly massive, above which in the soil by the side of the incline, are numerous pieces of the Sunbury black shale. From the top of the Berea sandstone on the incline to the base of the "City ledge," or Buena Vista sandstone, opposite the top of the plane is 21 feet. The excavation for the cistern at the head of the inclined plane was made in the Sunbury shale, large quantities of which are shown on its dump.

The Buena Vista stone forms a prominent ledge just back of the top of the plane, and it has been worked more or less extensively for some distance along this bank of the stream toward its head. Not far from the present upper limit of the quarry, the "City ledge" and overlying shales furnished the following section:

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[1] *Second Ann. Rept. Geol. Surv. Ohio*, 1839 (?), p. 263. The name was given because the stone was extensively quarried and used in the city of Cincinnati (see page 264).

SECTION OF BUENA VISTA FREESTONE QUARRY.

No.		Thickness feet.	Total thickness feet.
7.	Soil	3 ±	24½
6.	Very argillaceous, no grit, olive, bluish and reddish colored shale, some of it mottled	8½	21½
5.	Mottled bluish and reddish argillaceous shale, containing concretions and concretionary layers. In places mainly reddish in color	2	13
4.	Bluish argillaceous, rather compact shale	5½	11
3.	Top of fine-grained massive Buena Vista sandstone or "City ledge." The weathered top of this layer is frequently of rather bluish to greenish tint and covered by a mass of beautiful specimens of *Spirophyton*, the tubes and fronds of which extend down for a few inches into the upper part of this layer	3+	5½+
2.	Greenish argillaceous shale parting	2½ in.	2½+
1.	Lower layer of Buena Vista sandstone; a brownish to bluish-gray, fine-grained massive sandstone which emits a decided petroleum odor when freshly struck. Also frequently of light gray and sometimes reddish-brown tint. Base of the "City ledge," which has a thickness of 5 feet 7½ inches in this quarry. This compact freestone is a valuable sandstone, and in this region it is much more important commercially than the Berea sandstone	2⅓	2⅓

The massive Buena Vista sandstone with the overlying shales are shown in Fig. 3.

The large blocks of Buena Vista sandstone from these quarries, containing numerous specimens of *Spirophyton*, apparently show that these markings are made by worms. Extending down into the stone from the fronds, which occur on or near the top surface of the stratum, at various angles are tubes, some of which are open and others are filled with clayey material. These tubes are apparently the holes in the fine sand in which marine worms lived. Crawling to the surface, and back again and about the opening of the tube, they made the smoothed and grooved space which has been termed the frond, as it was supposed to represent a sea weed buried in the sand.

It is clearly evident that the Sunbury shale (Waverly black slate) extends to the Ohio river, probably with a thickness of between 15 and 16 feet as given by Andrews,[1] above which is 5 feet 4 inches of fire clay and blue and drab shale, as given on Andrew's section. His section gives a thickness of 20 feet 9 inches from top of sandstone (Berea) to the base of the "City ledge" (Buena Vista stone), and my section for the same portion of the Waverly is 21 feet, or 3 inches greater, which is a very close agreement when it is remembered that the location of the two sections is two miles or farther apart. Succeeding the zone of fire clay and shale is the Buena Vista stone or "City ledge," in two layers separated by a shale parting of 2½ inches, with a total thickness of 5 feet 7½ inches.

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[1] *Geol. Surv. Ohio*, Pt. II, "Rept. Prog. Sec, Dist." [in 1869], 1870, p. 65; and see his "Section of Waverly rocks from the great Black slate of the Subcarboniferous limestone, as seen on the Ohio river," on "Map showing the Lower Coal-measures."

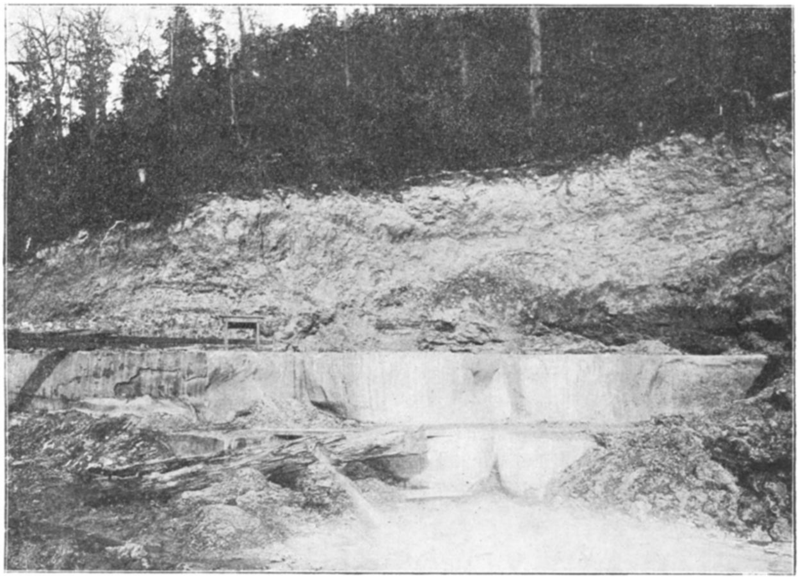

FIG. 3.—The two layers of Buena Vista sandstone and overlying shales on Lower Twin Creek, northwest of Buena Vista.

Professor Locke gave the thickness of the "City ledge" at Rockville as 2½ feet, and stated that it had "a stratum of shale about 15 feet below it," the context showing that he evidently meant the shale had a *thickness* of about 15 feet, "and another of about the same thickness above it."[1]

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[1] *Second Ann. Rept. Geol. Surv. Ohio*, p. 264.

The first distinct geographical name applied to the Sunbury shale was the "Waverly black slate," by Andrews, in 1870,[1] who gave its general thickness as 16 feet and its base as 137 feet above the top of the Ohio black slate, on Andrews' "Section of Waverly rocks . . . . on the Ohio river," however, the thickness of the Waverly black slate was given as 15½ feet, and its base as 134 feet above the top of the Ohio black slate.[2] The thickness of the "City ledge" was given by Andrews as 3 feet 5 inches near Rockville and 4½ feet on the Flagg land, probably on Lower Twin Creek,[3] and in 1871, in his "Section along the Ohio river from Adams to Lawrence counties," he reported it as 4 feet thick.[4]

Dr. Orton, in 1882, published a general statement concerning the formations in the vicinity of Buena Vista, in which he stated:

> The Bedford shale is still distinguishable with normal thickness, but carrying a relatively larger proportion of stone than to the northward. The Berea grit is clearly recognizable in the so-called "cliff stone," which has been quite largely worked here. The Berea shale (Waverly black shale) is a constant guide to the true order. The Buena Vista stone makes, as elsewhere, the base of the Cuyahoga shale, which is charged with more frequent freestone beds than to the northward.[5]

Finally, Herrick, in 1891, in his section of the southern exposures of the Waverly near Portsmouth, gave the thickness of the Berea black shale (Sunbury) as 15 feet, below which was from 30 to 40 feet of Berea grit flags.[6]

Vanceburg.—On the Kentucky side of the Ohio river about five miles below Buena Vista is Vanceburg at the eastern end of which is a steep and high hill known as Alum Rock.

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[1] *Geol. Surv. Ohio*, Pt. II, "Rept. Prog. Sec. Dist." [in 1869], p. 66.

[2] *Ibid.*, "Map showing the Lower Coal-measures."

[3] *Ibid.*, p. 66.

[4] *Proc. Am. Phil. Soc.*, Vol. XI, p. 245.

[5] *Proc. Am. Assoc. Adv. Sci.*, Vol. XXX, p. 174.

[6] *Bull. Geol. Soc. Amer.*, Vol. II, p. 40.

SECTION OF ALUM ROCK.

No.		Thickness feet.	Total thickness feet.
6.	Top of massive sandstone, capping first knob, which lithologically closely resembles the "City ledge" of Buena Vista region, while on top and in the upper part of the stratum are numerous specimens of *Spirophyton* similar to those described in the Lower Twin Creek quarry. The top of this sandstone, however, is 51 feet above the top of the Berea sandstone, while in the Lower Twin Creek it is only 26½ feet, so that it appears somewhat doubtful whether these two exposures are in the same layer. Loose blocks of sandstone containing *Spirophyton* occur at the elevation of 27 feet above the top of the Berea sandstone, and this layer perhaps represents the horizon of the "City ledge" as shown to the northwest of Buena Vista. All of this slope below the massive sandstone at top is covered	38	423
5.	Thin, black, even argillaceous shale, 13 feet shown before it is covered by soil. *Sunbury* (*Waverly black shale*)	13	385
4.	Top of massive *Berea sandstone;* some of the layers thick, light gray in color, rather course grained and weathering brownish. Some of the layers have magnificent specimens of ripple marks. The layer just below the top one is 3 feet thick, and on the top surface are splendid ripple marks	21	372
3.	Perhaps the rocks are mainly gray or greenish to bluish-gray shales, weathering to an iron color; but there are sandstone layers, some irregular or concretionary, often ripple marked, frequently thick, one of them 26 inches, and *Spirophyton* occurs. *Bedford formation*	75	351
2.	Covered. Plenty of yellowish iron stained arenaceous shales in soil. Perhaps all or the greater part of this zone belongs in the Bedford formation	21	276
1.	Black thin layered Ohio shale. Near the top of the shales are a few fossils, as a large *Lingula.* Partly covered slope, but probably all Ohio shale to the level of the Chesapeake and Ohio railroad; 255 feet by the barometer from railroad level to highest outcrop of shale	255	255

The Alum Rock section clearly shows that the Sunbury shale crosses the Ohio river, and has a thickness of at least 13 feet in the vicinity of Vanceburg. It was not followed farther south in Kentucky and at present it is not known how far it can be traced in that state.

NORTHERN OHIO.

From near Sunbury, Delaware county, northward there are no reported surface exposures of the Sunbury shale across Morrow, Crawford, Richland, Huron, and Lorain counties to the western part of Cuyahoga county. As a rule, however, the older formations of this part of the state are deeply covered by drift deposits, so that outcrops are infrequent, and it is not strange that this thin deposit of shale has not been reported. Its continuation, however, appears to be conclusively shown by the records of numerous wells drilled in these counties, in which a black shale of variable thickness was penetrated just above the Berea sandstone. Some of these wells are mentioned below, in all of which the Sunbury (Berea) shale was noted at its proper stratigraphic position, immediately above the Berea grit. At Mt. Vernon, Knox county, the top of the Berea grit is reported at a depth of 470 feet;[1] in Richland county, at Mansfield, it is 640 feet in depth, with 40 feet of Sunbury shale above;[2] at Crestline 113 feet in depth;[3] at Shelby 141 feet,[4] with 23 feet of Sunbury shale on top; at New London, Huron county, 165 feet;[5] at Wellington, in Lorain, 138 feet, above which is reported 30 feet of black shale;[6] and at Belden from 10 to 25 feet of Sunbury shale.[7]

Berea.— Dr. Newberry in his "Report on the geology of Cuyahoga county," stated that at Berea, in the western part of the county, "that portion of the Cuyahoga shale which immediately overlies the Berea grit contains myriads of *Lingula melie* and *Discina Newberryi*,"[8] but there was no suggestion of separating this fossiliferous deposit from the Cuyahoga shale. In 1875 Meek mentioned "the dark shales of Berea" in an explanation of a figure of *Discina* (*Orbiculoidea*) *Newberryi* from that locality, and used the expression "Berea shale."[9]

Quarry No. 6 of the Cleveland Stone Company at Berea furnishes the following section:

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[1] *Rept. Geol. Surv. Ohio*, Vol. VI, 1888, p. 366.

[2] *Ibid.*, p. 365.

[3] *Ibid.*, p. 303.

[4] *Ibid.*, pp. 316 and 365.

[5] *Ibid.*, p. 440.

[6] *Ibid.*, p. 348.

[7] *Ibid.*, p. 332.

[8] *Rept. Geol. Surv. Ohio*, Vol. I, Pt. I, 1873, p. 185.

[9] *Rept. Geol. Surv. Ohio*, Vol. II, Pt. II, Pl. XIV, explanation of Figs. 1c and 1d.

SECTION OF QUARRY NO. 6.

No.		Thickness feet.	Total thickness feet.
4.	*Erie clay* to top of bank - - - - - - - - - -	11	50
3.	Top of *Sunbury* (*Berea*) *shale.* It is mainly a black, quite massive bituminous shale; but some of it as weathered is rather bluish in color. Thin layers contain specimens of *Lingula melie* H., but they are not abundant in that portion of the shale which is exposed at this locality - - - - - - - - -	8⅔	39+
2.	Probably all of this zone is in the *Sunbury shale;* but it is partly covered and the contact with the subjacent Berea grit is poorly shown - - - - - - - - - - - - - -	3	30½—
1.	Top of the *Berea grit.* A layer from 7 to 16 inches in thickness, and perhaps more, forming the upper part of the Berea sandstone is hard, contains plenty of iron pyrites, is not valuable for stone and weathers into a somewhat shaly layer - - -	27½—	27½—

There are four prominent courses of the Berea grit as worked in this quarry, with the following thicknesses: Course No. 4, including the pyrite layer at the top, 5 feet 4 inches; course No. 3, 6 feet 8 inches; course No. 2, 7 feet 1 inch; No. 1, 6 feet 4 inches. Below this 2 feet of sandstone is shown at the bottom of the quarry without reaching the base of the Berea grit.

In quarry No. 8, adjoining the one just described, they have drilled into the Berea sandstone to the depth of 52 feet, and Newberry stated that in Cuyahoga county it is "something like 60 feet in thickness."[1] In this quarry there is more shaly sandstone at top than in No. 6 and a clay pebbly layer near the top contains a few specimens of *Camarotœchia.* The following section is for the eastern end of the quarry, with the exception of its upper portion which was obtained on the northern bank.

SECTION OF QUARRY NO. 9.

No.		Thickness feet.	Total thickness feet.
4.	*Erie clay* to top of bank - - - - - - - - -	10½	91¾
3.	On the northern wall black shale or grayish-black when weathered - - - - - - - - - - - - -	13¼	81¼
2.	Black bituminous shale, some of it with a bluish tint, containing numerous specimens of *Lingula melie* Hall and some of *Orbiculoidea Newberryi* (Hall) Herrick. *Sunbury shale* - - - -	11	68

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[1] *Loc. cit.*, p. 186.

1. Top of *Berea grit*. This course, No. 7, composed of shaly sandstones layers generally thin and containing plenty of iron pyrites; not valuable quarry stone, 5 feet two inches. Course No. 6, 4 feet; course No. 5, 8 feet 4 inches; course No. 4, 7 feet 7 inches; course No. 3, 6 feet 3 inches; course No. 2, 10 feet; course No. 1, 15 feet 6 inches. Floor of the quarry but not the bottom of the grit. Courses 1 to 6 inclusive are all composed of good massive quarry stone with a total thickness of 51 feet 8 inches. When freshly quarried the stone is of light gray color; but on weathered surfaces it is not infrequently stained from the decomposition of iron pyrites - - - - - - - - - 57 57

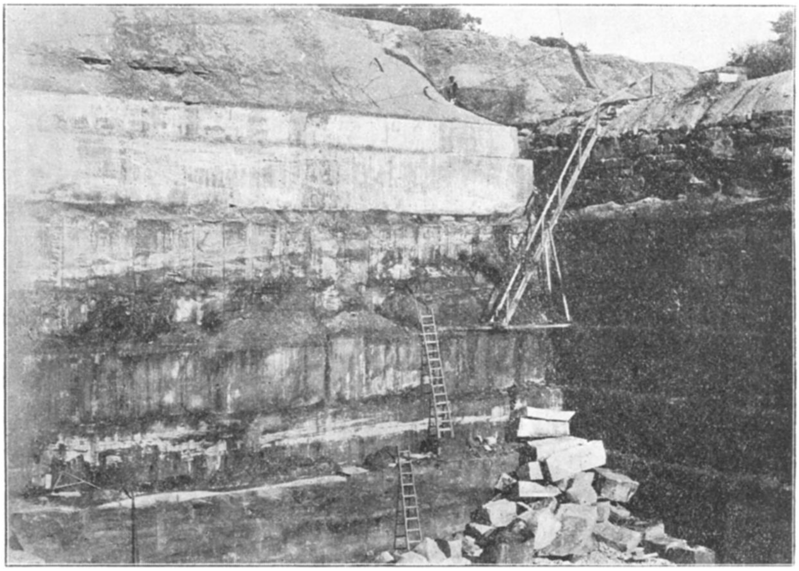

FIG. 4.—Berea grit with superjacent Sunbury shale in quarry No. 9, at Berea.

This section shows that there is not such a marked and sharp lithologic change from the Sunbury to the Cuyahoga shale as is found in the bluffs of the Ohio river or is shown in sections farther east, but a more gradual transition. This quarry is shown in Fig. 4, the greater part of which is the Berea grit, but capped by the Sunbury shale, and fossils are abundant in the zone indicated by the man.

Bedford.—In the vicinity of Bedford, in the southern part of Cuyahoga county, on the banks of Tinker's Creek, are several good vertical sections from the Bedford shale or Berea grit into the Cuyahoga shale. Three of these will be given, and their comparison will show some lithologic variation in a comparatively short distance. The following is a section of the south bank of Tinker's Creek under the bridge of the Akron, Bedford & Cleveland electric road.

SECTION AT THE A. B. & C. ELECTRIC BRIDGE.

No.		Thickness feet.	Total thickness feet.
5.	Gray to bluish-gray shale, with an occasional blackish streak, which breaks into very small pieces as weathered and shown on the upper part of the bank. No fossils were found	10⅚	51
4.	Alternating shales and sandstones of bluish-gray color, the sandstone predominating. *Cuyahoga shale*	8¼	40¼—
3.	Thin argillaceous bluish-gray shales splitting into small pieces. At the base a blackish bituminous shale 1 inch in thickness, which splits into thin, smooth layers, and contains *Lingula melie* Hall. In lithologic appearance only the 1 inch of blackish shale at the base of this shale zone resembles the *Sunbury shale* of southern and central Ohio and the eastern part of Cuyahoga county, and this is not as black as typical Sunbury shale. It is probable, however, that the blue color and other characters of this shale are a local variation, and that all of this zone may be referred to the Sunbury shale. If not, then at this locality it has thinned to the 1 inch of black, fossiliferous shale noted at the base of the zone	$5\frac{5}{12}$	32—
2.	Top of *Berea grit;* massive grayish, rather coarse-grained sandstone	21½	26½
1.	Shaly to thin-bedded blue sandstone to creek level, all of which is in the Berea grit. There are plenty of ripple marks on the sandstone in the bed of the creek	5	5

Farther down the stream the following section is shown on the eastern bank of the creek a little above the Bedford rolling mills.

SECTION ABOVE BEDFORD ROLLING MILLS.

No.		Thickness feet.	Total thickness feet.
3.	Gray, fine-grained, thin-bedded sandstone, alternating with layers of shale, the sandstone predominating. Base of *Cuyahoga shale*	7⅓	35
2.	Thin-bedded argillaceous shales which are mainly of gray color, but passing from blackish-gray to black bituminous shales. At the base *Lingula melie* H. and *Orbiculoidea* occur sparingly. *Sanbury shale*	6	27⅔

1.	Massive *Berea grit;* some of the upper layers thin-bedded, partly covered slope to creek level, and only about the upper half of the formation exposed - - - - - - - -	21⅔	21⅔

The best section of these formations in the vicinity of Bedford, however, is that on the northeast bank of Tinker's Creek, between the Bedford rolling mills and the Cleveland and Pittsburgh railroad viaduct, Fig 5. A dam for an electric light plant is being constructed not far below this locality so that later the lower part of the section may be concealed by water.

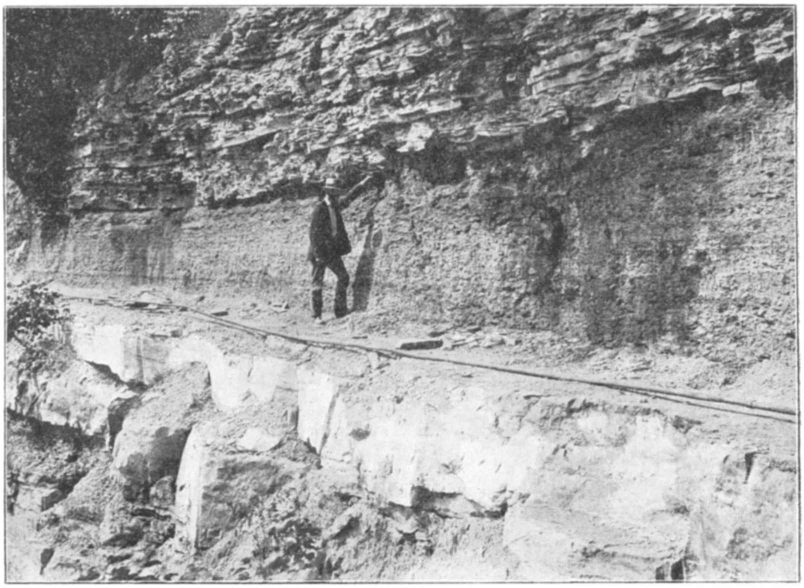

FIG. 5.—Sunbury shale above C. and P. R. R. viaduct, Tinker's Creek, Bedford. The man is standing on top of the Berea grit and indicating with his hand the contact of the Sunbury and Cuyahoga shales. The thin sandstones in the lower part of the Cuyahoga are clearly shown.

SECTION ABOVE THE C. & P. RAILROAD VIADUCT.

No.		Thickness feet.	Total thickness feet.
4.	Mainly thin-bedded, light gray sandstone, with shale partings to top of the bank. At base thin-bedded, light gray, fine-grained sandstone. Base of *Cuyahoga shale* - - - -	7½	71—

3. Blackish shale near top of zone. Very fine argillaceous shale which is mainly bluish-gray to gray in color, but with some blackish layers. It is finely shown on the bank above the quarry. *Sunbury shale* - - - - - - - - - -	6	63⅓
2. Top of *Berea grit* at top of quarry. Light to dark gray or rusty-brown color, rather harder and finer-grained sandstone than the lower courses, 3⅙ feet. Massive, light gray, coarse-grained grit, often weathers yellowish, 3⅔ feet. Light gray, or frequently weathered to iron color, thin-bedded to shaly sandstone, 3⅙ feet. Massive, light gray, coarse-grained sandstone to grit. Ripple marks occur in lower part, 29⅓ feet - -	39⅓	57⅓
1. Contact of *Berea grit* and *Bedford shale.* Upper part of Bedford composed of bluish-gray argillaceous shales. Lower shales alternating with thin layers of sandstone, 1 inch or more in thickness, to creek level - - - - - - - -	18	18

It appears that No. 4 of Dr. Newberry's "Section of strata at Bedford," which he described as a gray shale from four to six feet thick and classed in the Berea grit,[1] is the equivalent of what is called the Sunbury shale in the above sections. Dr. Newberry also included the superjacent zone of thin bedded sandstone (No. 3 of his section) in the Berea. It is the writer's impression that he was in error in this particular, and that the top of No. 5 of his section should be considered as the line of separation between the Berea grit and the overlying formation, now called the Sunbury shale, but in the time of his reports considered as the base of the Cuyahoga shale. The zone termed the Sunbury shale in the above sections is composed of a very argillaceous, thin-bedded shale, mainly gray to bluish-gray in color, with bands of black shale. It appears to the writer that this shale represents the Sunbury shale of central Ohio, but that it has largely lost its black and bituminous character. Remove Nos. 3 and 4 from the Berea grit of Newberry's section and there remains but No. 5 of his section for the Berea, which he described as a "thick-bedded yellow sandstone with ripple marks," 45 feet in thickness; while in the above section we have a thickness of 39½ feet for the Berea. The Sunbury shale of the above section is well shown in Fig. 5, where the man is standing on top of the Berea grit and pointing to the line of contact of the Sunbury and Cuyahoga shales.

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[1] *Rept. Geol. Surv. Ohio*, Vol. I, Pt. I, 1873, p. 197.

Chagrin Falls.— In the eastern part of Cuyahoga county, on the bank of Chagrin River, above Chagrin Falls, is a fine outcrop of the Sunbury shale. The following section was made at the Goodale quarry opposite the paper mill above Chagrin Falls :

SECTION OF GOODALE QUARRY ABOVE CHAGRIN FALLS.

No.		Thickness feet.	Total thickness feet.
3.	Black, bituminous shale, which weathers on the edge frequently to a rusty color, and is a massive shale under cover. The lower foot of the shale contains immense numbers of *Lingula melie* H. and a smaller number of a large species of *Lingula* and *Orbiculoidea Newberryi* (Hall) Herrick. There are also fragments of fish and plants. The fossils are the most abundant in the lower foot of the shale, but they occur in considerable force for at least 2½ feet above the base, and specimens were collected in the shales at the height of 4 feet. *Sunbury shale* - -	11	20
2.	Top of *Berea grit.* Massive coarse-grained layer, friable rock, easily crumbling in the fingers, 3½ feet thick. At the lower end of the quarry the upper part splits into thin, rather irregular flags, and there is no massive layer at top. Thin bedded to shaly sandstone, part of which makes flagging. The flags show ripple marks, and some of the layers are worthless; 2½ feet exposed - - - - - - - - - - - - -	6	9
1.	Covered to river level - - - - - - - - - -	3±	3

This is the best locality noted in the Sunbury shale for collecting fossils, and attention was first called to it by Dr. Newberry.[1] The above section is shown in Fig. 6, where the man is standing on one of the layers of Berea grit and indicating with his hand the contact of the Berea and Sunbury shale.

Warren.—Across Lake, Geauga, Ashtabula, and Trumbull counties, there are comparatively few outcrops of the Sunbury shale, and as a rule even the Cuyahoga shale is concealed by drift deposits. On the bank of the Mahoning river, however, above Warren, are excellent outcrops of the Sunbury shale. One of these may be found on the eastern bank below the house of Alfred Fitch, rather more than one-fourth of a mile above the Water Works.

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[1] *Rept. Geol. Surv. Ohio*, Vol. I, Pt. I, 1873, p. 185.

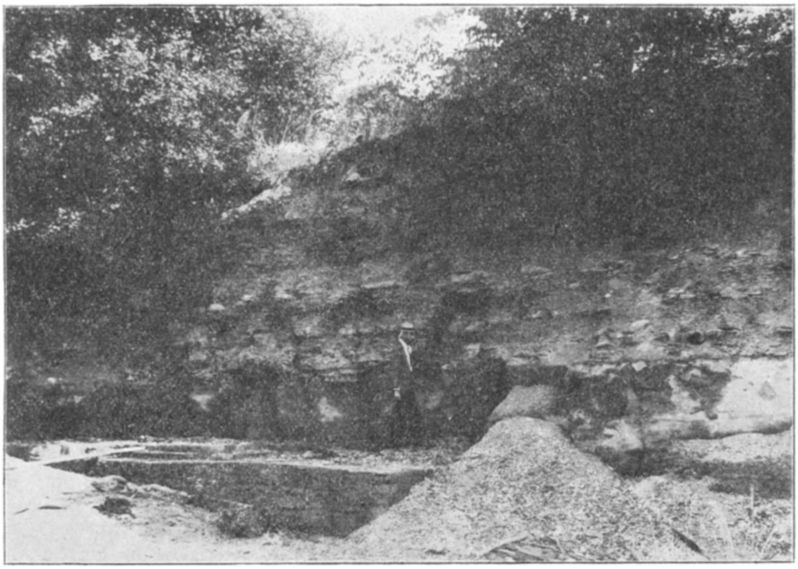

FIG. 6.—Contact of Berea grit and Sunbury shale in Goodale quarry, Chagrin Falls, indicated by the man's hand.

SECTION ON MAHONING RIVER ABOVE WARREN.

No.		Thickness feet.	Total Thickness feet.
5.	Soil and clay - - - - - - - - - - -		
4.	Sandy layers to sandstone - - - - - - - -		
3.	Bluish-gray compact sandstone. Base of *Cuyahoga formation*	¾	16¾
2.	Top of shale rather impure and sandy, perhaps in places 1 foot of sandy shale at top. Black to brownish-black shale, some of it very black and compact, in lithologic characters similar to the Sunbury shale. The lower part of the shale contains immense numbers of *Lingula melie* Hall and a smaller number of specimens of another species of *Lingula*. *Sunbury shale* - - -	14	16
1.	Top of *Berea sandstone*. Fairly fine-grained, very uneven bedded sandstone, which contains a large quantity of iron pyrites. A little below, in thinner layers, are numerous ripple marks. The sandstone appears above water on the arch of a small anticlinal fold. At the time it was studied the upper 2 feet of the formation was exposed, while on the river bank, both above and below this locality, the Sunbury black shale runs down to water level - - - - - - - - -	2±	2

On the same bank of the river about ¼ mile below the section just described and a short distance above the Water Works is the following section, the rocks of which are apparently above those of the former section and in the lower part of the Cuyhoga formation.

SECTION ABOVE WARREN WATER WORKS.

No.		Thickness feet.	Total thickness feet.
7.	Soil and till		
6.	Apparently shale		
5.	Bluish-gray sandstone	¼±	16
4.	Soft bluish-gray, very argillaceous shale	2¾	15¾
3.	Compact layer of bluish-gray, fine-grained sandstone	¾±	13
2.	Blackish shales at top containing specimens of *Lingula*. The shales are mainly bluish-black; but contain thin bituminous layers, especially in the upper part, and alternating with the shales are thin layers of bluish sandstone, which are thicker near the base of the cliff, and some are slightly concretionary, weathering to a decided rusty color. Specimens of *Lingula* are numerous in the blackish shales near the top, and some were also collected in the blackish shales near the base of the section	11	12⅓
1.	At the upper end of the exposure, where the rise brings up the lower rocks, we find that below the shales of No. 2 are coarse arenaceous shales to bluish-gray sandstone, about 1⅓ feet shown. This stratum is apparently the sandstone zone occurring on top of the Sunbury shale. Level of Mahoning river	1⅓	1⅓

The prominent sandstone layer at the southern end of the cliff is 9 feet 10 inches above water level, and 420 feet farther north, at the northern end, 12 feet 4 inches above the water, giving a dip of 2 feet 6 inches for that distance to the southeast or at the rate of 31 feet per mile. This section is considered as in the lower part of the Cuyahoga formation, and shows that its lower shales are blacker than those near the base of the formation in northern and central Ohio, and somewhat similar to those of the subjacent Sunbury shale.

On the western bank of the Mahoning river, 1½ miles from the court house park in Warren, on the farm of Warren Brobst, the anticlinal fold already noted on the eastern bank brings up the Berea sandstone. At the base about four feet of Berea sandstone is shown above low water, which is mainly thin-bedded.

The layers are buff in color, more or less undulating, and some of them have ripple marks. Just above is the black Sunbury shale in the lower part of which are immense numbers of *Lingula melie* Hall, together with a larger *Lingula* which is not nearly so abundant.

Above Edgewater, a mile or more beyond the locality just described, is a rocky bank which shows the following section: At the base a blackish fissile shale, about eight feet in thickness; at the top of the shale is a thin sandstone, above which is another zone of shale, capped by a thin sandstone. The Berea sandstone is not shown at the river level and the exposed shales and sandstones apparently belong to the lower part of the Cuyahoga formation.

M. C. Read wrote the geological report of Trumbull county, and under the description of "the Cuyahoga shale" he stated that:

> In the bed of the Mahoning west of Warren, the abundance of *Lingulæ* and the lithological peculiarities indicate that the stream at this point cuts nearly through these shales, and that the Berea grit is to be found at no great depth below.[1]

From the above statement it is evident that Read did not find or recognize the Berea grit in the Mahoning river above Warren. It is of course possible that he did not visit the locality where the anticlinal fold crosses the river and brings up the Berea so that he did not see the top of the formation, or perhaps the water was considerably higher at the time of his work, and the sandstone was covered.

Mr. Read appears to have been confused regarding the horizon of the Berea grit near the state line, a point which has been elucidated by Dr. I. C. White[2] and Professor H. P. Cushing who identified the formation in the vicinity of Warren. Professor Cushing's statement is as follows: "North of Warren another sandstone appears directly under the black shale [the Sunbury or Berea shale] and is the equivalent of the lowest sandstone on the state line, of the *Corry* sandstone of Professor White in Pennsylvania, of the Berea of northern Ohio.[1]

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[1] *Rept. Geol. Surv. Ohio*, Vol. I, Pt. I, 1873, p. 504.

[2] *Second Geol. Surv. Pa.*, Q^3, pp. 60 f., 62, 63 f., and Q^4, pp. 77 f., 85, 86.

Professor Cushing gave a section of the rocks through Warren in which the Berea shale (Sunbury) is given as 55 feet in thickness.[2]

It is evident that he included in the Berea shales the blackish ones which the writer has referred to the lower part of the Cuyahoga formation, for it seems to him that only the 14 feet of black shales exposed on the bank of the Mahoning river, and included between the top of the Berea grit and the base of the overlying 9-inch blue sandstone, are to be regarded as the equivalent of the Sunbury black shale as exposed at the typical localities of Sunbury, and in the bluffs of the Ohio river near Buena Vista.

Dr. Orton stated that "in Trumbull county of northeastern Ohio, the Berea [Sunbury] shale grows very thin and thus the upper quarry courses come down close upon the Berea grit."[3] Later he wrote:

> The Berea shale seems to be reduced in this region [Warren] to a thickness of about 8 or 10 feet. It is, however, well characterized by the Discina and Lingula which belong to the horizon. In many places it is almost entirely composed of these shells.[4]

While in describing the Berea grit in the vicinity of Cortland, 7 miles northeast of Warren, Dr. Orton stated:

> It is always overlain by a thin but very black fossiliferous bed of the Berea shale. An excellent section is furnished in the banks and the bed of Walnut Creek, within the limits of the village of Cortland, and a half-mile below. At the junction of Walnut and Musquito creeks, the flag-rock that makes the upper bed of the Berea is found in the bed of the stream. It is covered by 8 feet of Berea shale, very black and crowded with its characteristic fossils.[5]

Mr. John F. Carll, who described such a large number of oil well sections for the Pennsylvania survey, regarded the Berea grit as probably identical with the Pithole grit of Venango county, Pennsylvania.[1] Dr. I. C. White included the Pithole grit in his " Oil Lake group," which he described as "composed of the *Corry* and *Cussewago sandstone* and the included *Cussewago limestone* and *shale*,"[2] and stated that the Corry sandstone, which he correlated with the "Third Mountain Sand of Venango,"[3] "passes into Ohio and continues west as Dr. Newberry's *Berea grit* outcrop."[4]

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[1] *Proc. Am. Assoc. Adv. Sci.*, Vol. XXXVI, 1888, p. 215.

[2] *Ibid.*, p. 214, No. 3.

[3] *Ibid.*, Vol. XXX, 1882, pp. 173, 174.

[4] *Rept. Geol. Surv. Ohio*, Vol. VI, 1888, p. 321.

[5] *Ibid.*, p. 331.

Dr. Orton thought that the Sunbury shales became very thin in Trumbull county, so that the flagging stone near Warren, which he regarded as the equivalent of the Buena Vista stone of southern Ohio and the Sharpsville sandstone of Pennsylvania,[5] came " down close upon the Berea grit." Finally, regarding the correlation, he stated: "I am disposed to believe that the Pithole grit of Pennsylvania, as reported in many borings of the region, consists of this joint product of the two systems" [the Buena Vista and Berea sandstones].[6] Later it was stated that Dr. White's "Sharpsville sandstone is our Buena Vista stone, and his Corry sandstone appears to be none other than the Berea grit."[7]

Orangeville.— This village in the Pymatuning valley on the state line is located partly in Trumbull county, Ohio, and partly in Mercer county, Pa. On the southern bank of the Pymatuning Creek, just below the bridge and dam in Orangeville on the Pennsylvania side, is a bank composed mainly of bluish-gray shales, which gave the following section:

SECTION AT ORANGEVILLE.

No.		Thickness feet.	Total thickness feet.
5.	Dark gray to bluish-gray argillaceous shales which contain some small iron-like concretions - - - - - - -	10½	22

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[1] *Second Geol. Surv. Pa.*, I^3, 1880, pp. 91–97 and I^5, 1890, pp. 94, 97–105.

[2] *Ibid.*, Q^4, 1881, p. 91. [3] *Ibid.*, p. 92. [4] *Ibid.*, p. 94.

[5] *Rept. Geol. Surv. Ohio*, Vol. VI, 1888, p. 38, and Vol. VII, 1893 [1895], p. 31.

[6] *Proc. Am. Assoc. Adv. Sci.*, Vol. XXX, 1882, p. 174.

[7] *Rept. Geol. Surv. Ohio*, Vol. VII, 1895, p. 33.

4.	Bluish-gray sandstone weathering to a rusty color, from 6 to 8 inches in thickness - - - - - - - - - - -	$\frac{1}{2}$+	11$\frac{1}{2}$
3.	Grayish to bluish-gray shales, argillaceous and slightly gritty containing some specimens of *Chonetes* and *Lingula* - -	4$\frac{5}{12}$	10$\frac{5}{6}$
2.	Bluish-gray sandstone which weathers to a rusty color, 5 inches thick - - - - - - - - - - - - - -	$\frac{5}{12}$	6$\frac{5}{12}$
1.	Rather bluish argillaceous shales, which, near creek level, are more arenaceous and bituminous, containing numerous specimens of *Lingula melie* Hall and *L. cuyahoga* Hall - - -	6	6

All of the above shales weather to a rusty color on exposure, contain fossils, are blacker than those of the lower Cuyahoga shale in the Cleveland region, and in addition contain a much larger number of specimens of *Lingulæ*. It is the writer's opinion that the above shales are in the lower part of the Cuyahoga formation and above the Sunbury or Berea black shale.

These rocks were named the Orangeville shales by Dr. I. C. White, who stated that the name was used " merely for the convenience of avoiding in this report a premature discussion of the question of its identification with the Waverly black shales of Andrews, or lower member of the Cuyahoga shale of Newberry."[1] He described it as : " A group of shales, prevailingly blue, but often rusty or reddish-brown on exposed surfaces, always more or less argillaceous, seldom exhibiting sandy layers more than 6 inches thick; and containing considerable quantities of scattered iron ore balls," with a thickness of about 75 feet at Orangeville.[2] While under the description of Pymatuning township, in which the eastern part of Orangeville is located, is the following account of the cliff below the Orangeville street bridge: "The horizon is *300 feet below that of the Sharon coal*, and therefore under the *Cuyahoga shale*. The upper portion of this exposure consists of reddish-gray shales, interstratified with thin flaggy layers; but down near the creek level the shales begin to grow much finer and darker; and just below the mill-dam fragments of a dark-bluish fine-grained shale in the water-bed are perfectly filled with *Discina pleurites* and *Lingula melie*, This can hardly be the *Cleveland shale* of Dr. Newberry."[3] In the succeeding report, Dr. White spoke of the Orangeville shales as "these bottom deposits of the *Cuyahoga formation* of Ohio."[1] Dr. Orton stated that "White's Orangeville shale is an equivalent of our Berea shale."[2]

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[1] *Second Geol. Surv. Pa.*, Q^3, 1880, p. 63. [2] *Ibid.*, p. 63. [3] *Ibid.*, p. 160.

Mr. W. F. Cooper, in a brief discussion of the Berea shale, states that it "varies in Ohio from 15 to 50 feet in thickness throughout the line of outcrop, and is an exceedingly persistent and well-defined horizon. In northeastern Ohio, near the Pennsylvania line, it lies immediately under the Carboniferous millstone grit; a fact of importance in the development of the Lower Carboniferous of that state, which has heretofore been misunderstood."[3] Mr. Cooper is in error in the above statement regarding the horizon of the Sunbury (Berea) shale, for on the hill and farm of Charles Troutman, about two miles north of Orangeville, the base of the Sharon conglomerate (Millstone grit) is barometrically 270 feet above the level of the Pymatuning Creek in Orangeville, at the base of the cliff of Orangeville shales.

Dr. George H. Girty in recent years has devoted a great deal of time to the study of the Waverly series, and he differs from Dr. I. C. White and Professor Cushing, who correlated the Berea grit with the Corry sandstone of Pennsylvania, in regarding it as "the equivalent of the Cussewago sandstone of northwestern Pennsylvania,"[4] the top of which, according to the *Pennsylvania Reports*, is stratigraphically about 35 feet below the base of the Corry sandstone. Dr. Girty stated: "It is doubtful if the Corry sandstone is represented in Ohio." Dr. Girty further stated that "the Orangeville shale of that region is the basal third of the Cuyahoga shale, in part equivalent to Orton's Berea shale,"[5] in which statement the writer would fully concur, for Dr. I. C. White, in his reference to the outcrops near Warren, apparently included the Sunbury shale in the Orangeville shales.[1]

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[1] *Ibid.*, Q^4, 1881, p. 89, and see p. 90 f.

[2] *Rept. Geol. Surv. Ohio*, Vol. VII, 1895, p. 33.

[3] *Geol. Surv. Mich.*, Vol. VII, Pt. II, 1900, pp. 286, 287.

[4] *Science*, N. S., Vol. XIII, April 26, 1901, p. 664.

[5] *Ibid.*

After the above was written the writer learned that a test well was being drilled in Orangeville, Ohio, and he is indebted to Messrs. W. J. Apthorpe and J. D. Burnett, of that town, for information concerning it and samples of the drillings. The mouth of the well is in the creek valley above the State-street bridge, estimated as about 6 feet higher than the milldam, which would make it about 10 feet higher than the base of the shales exposed on the creek bank below the dam. It is reported that the creek alluvium is 17 feet thick in the well and at that depth shale was struck. The first sample submitted to the writer, from the depth of 42 feet, is reported as the first sand struck in the well and from the top of the Berea grit. The sample is composed mainly of light-gray silicious and very micaceous sandstone, with an occasional grain of iron pyrites, and lithologically closely resembles the Berea grit. Mixed with the sandstone chips is an occasional one of black shale, which is evidently from above the sandstone. This light gray sandstone is reported to continue to 122 feet, and a sample from 50 feet and another from between 57 and 117 feet are from a light gray, very silicious sandstone. The sample from 117 to 122 feet is composed of fine light gray to white quartz sand with some grains of iron pyrites and its bottom is thought by Mr. Burnett to represent the base of the Berea grit. Immediately below this, Mr. Apthorpe reports 3 feet of shale; but the sample from 122 to 164 feet is composed mainly of quartz sand. Mr. Burnett, however, reported that at 122 feet the drill entered a softer sand. The sample from 164 to 170 feet is composed of bluish argillaceous shale with a white streak and bluish-gray or gray arenaceous shale to thin micaceous sandstone. From 170 to 415 feet, the chips are mostly dark gray in color and apparently mainly from arenaceous shale. The data furnished by this well, taken in connection with the barometric section from the level of the Pymatuning Creek and the Sharon conglomerate, on the Troutman farm north of Orangeville, apparently show that in the vicinity of Orangeville there is an interval of about 300 feet between the base of the Sharon conglomerate and the top of the Berea grit. There is some uncertainty as to what should be considered the base of the Berea grit. If the line is drawn at the top of the 3 feet of shale, reported at the depth of 122 feet, then the Berea will have a thickness of 80 feet. The sample, however, from 122 to 164 feet is composed mainly of rather large pieces of quartz sand and is apparently from a massive sandstone. If this lower sandstone be classed in the Berea grit, then it will have a thickness of 122 feet. The well has been drilled to a depth of 1715 feet, and the deeper samples are mainly from bluish to grayish argillaceous shales, together with some from grayish arenaceous shales and thin grayish sandstones, apparently in the Erie shale. The samples showed no indication of the black Cleveland shale, so that it is impossible to give the base of the Bedford or top of the Erie shale in this record.

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[1] *Second Geol. Surv. Pa.*, Q^4, p. 90 f., where it is stated that "here also it [Orangeville shale] is darker and even some thin layers bituminous, which goes to support Professor Orton's identification of it with Professor Andrews's *Waverly black slate* of southeastern Ohio."

An examination of Dr. Orton's description of the well records of this region leads the writer to conclude that he referred all the sandstone at this horizon to the Berea grit. Dr. Orton reported the Berea grit "to have a thickness of 100 feet, or even more"[1] in the Mecca oil field to the northwest of Orangeville, in the northern central part of Trumbull county. In the wells near Youngstown, which is southwest of Orangeville, in the northern part of Mahoning county, it is given as from 150 to 160 feet thick "with a thin bed of shale interstratified about half way down."[2] While still farther south in the East Liverpool gas field, in the southeastern corner of Columbiana county, in the Ohio river valley, Dr. Orton stated that "the Berea grit ranges in this territory from 60 to 120 feet in thickness."[3] From a well near Sharon, in the western part of Mercer county, Pa., about seven miles south of Orangeville, the Pennsylvania geologists have reported a white, sharp sandstone, 75 feet thick, the top of which is 313 feet below the base of the Sharon conglomerate;[1] which Mr. Carll regarded as probably identical with the Pithole grit of Pennsylvania and the Berea grit of Ohio.[2]

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[1] *Rep. Geol. Surv. Ohio*, Vol. VI, p. 331.

Ibid., pp. 402, 403. [3] *Ibid.*, p. 333.

CONCLUSION.

It has been shown in this article that the Sunbury shale is in general a well-marked and sharply-defined lithologic division, which extends from Vanceburg, in northern Kentucky, across Ohio to the eastern part of Trumbull county, and perhaps into Pennsylvania. It is usually thin, fissile, black, strongly bituminous, varying in thickness from about 6 to nearly 28 feet. The lower part of the shale is very compact and tough, splitting into thin sheets of considerable size, which are somewhat arenaceous; frequently containing some iron pyrites, and often rich in fossils, especially inarticulate Brachiopods. Near Bedford, in northern Ohio, however, it loses its decidedly black color, and is mainly bluish-gray or blackish-gray, with some blackish bituminous layers. The base of the shale is always sharply separated from the underlying massive Berea grit. At the top, wherever exposed, it is also, lithologically, clearly separated from the overlying Cuyahoga formation, although the line of contact is not so well marked and conspicuous as the one at the base. In northern Ohio, at the base of the Cuyahoga formation, are bluish-gray alternating shales and thin sandstones, while in the bluffs of the Ohio river occur 5 feet of blue to drab fire clay and shale, which is followed by 5 ± feet of brownish to bluish-gray massive Buena Vista sandstone. Perhaps in Cuyahoga county the contact between the Sunbury and Cuyahoga shales is not so clearly defined as in most of the state, while again in Trumbull county and in the eastern part of the state there are bluish-gray to blackish shales in the lower part of the Cuyahoga formation, which resemble somewhat the subjacent

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[1] *Second Geol. Surv. Pa.*, Q^4, 1881, p. 70; also see I^3, 1880, Atlas, Pl. IV, Fig. 3, where the interval is given as 310 feet; Q^2, 1879, pp. 298, 303; and Q^3, 1880, p. 119.

[2] *Ibid.*, I^3, p. 93.

Sunbury shale. Still it is thought that even in this region the line of division is as sharply and clearly defined as is often the case between two formations. It appears to the writer to be a clearly marked and sharply defined lithologic division. Paleontologically, the lower portion of the shales frequently contains numerous specimens of a few fossils, principally *Lingula melie* Hall and *Orbiculoidea Newberryi* (Hall) Herrick, which may be considered the characteristic species of the formation, although not confined to it, since both species probably continue into the Cuyahoga formation.

Finally, on account of the marked lithologic character of the Sunbury shale, its sharp boundaries, its extensive, although narrow areal distribution, and its stratigraphic importance in the classification of the Waverly series, the writer would regard it as a distinct unit in the geological scale of Ohio.

On the geologic maps, based upon the *United States Topographic Sheets* for southern and central Ohio, it appears to the writer that the Sunbury shale is clearly entitled to be represented by a distinct symbol or color and given the rank of a formation. In the northern counties the shale is not always black and strongly bituminous, and the upper limit is probably not as clearly marked as in the southern part of the state.

In western Pennsylvania Dr. I. C. White has described the Orangeville shales and Sharpsville sandstone, while Professor Lesley used the provisional name of Crawford for the overlying shales,[1] all of which in a general way are synchronous with the Sunbury and Cuyahoga shales of northern Ohio. In the succeeding report Dr. White used the terms Meadville upper shales, Meadville upper limestone, and Meadville lower shales, in place of the Crawford shales,[2] and he writes me:

> The name [Crawford shale] was never used by me nor accepted, because it meant nothing. It was provisionally put in by Professor Lesley without my consent, and the following year when it was found this interval of rocks could be further subdivided in Erie and Crawford counties, it was done, and the name "Crawford shales," which I had never accepted, dropped.[3]

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[1] *Second Geol. Surv. Pa.*, Q^3, pp. 59 f., 61–63.

[2] *Ibid.*, Q^4, 1881, pp. 83–85.

[3] Letter, March 7, 1902.

The shales at Orangeville are dark to bluish-gray, differing as a rule considerably in structure and color from the Sunbury shale. It is evident that the black shale overlying the Berea grit, reported by Dr. Orton from many wells in northern Ohio as the Berea shale, includes more than that shale, and corresponds to the Orangeville shale of Dr. White. Some geologists believe that the Orangeville shale, comprising all the rocks on the eastern line of the state included between the top of the Berea and the base of the Sharpsville sandstone, is the lithologic unit which ought to be represented on the United States geologic maps of northern Ohio. This is the opinion of Professor H. P. Cushing and Dr. George H. Girty, and is entitled to careful consideration, especially since Dr. Girty writes that the Orangeville shale, Sharpsville sandstone, and Meadville shale "maintain themselves across northern Ohio and appear in Medina county in fairly characteristic aspect."[1]

If the Orangeville shale be accepted as the lithologic unit for mapping in northern Ohio, then the Sunbury shale will become the lower member of the Orangeville formation for that part of the state.

NOTE.—In an article entitled "The Classification of the Waverly series of Central Ohio," published in the JOURNAL OF GEOLOGY, the writer referred to the revised classification of the New York rocks by Dr. John M. Clarke and Mr. Charles Schuchert.[2]

It was intended to state, in the first place, that two principles of nomenclature which had been given, had been imperfectly observed by many geologists in their works on stratigraphical geology. In the second place it was intended to state that, on account of this more precise use of stratigraphic names, it had become necessary to revise even the classic nomenclature of the New York series of formations, in which case it was also found necessary to replace several old and well-known names by new terms. The reference to the revised New York classification was intended as a complimentary one, and as a precedent for similar revision of the classification of other states. These two ideas, however, were expressed in one sentence in a somewhat infelicitous manner which has led to some misunderstanding regarding the real meaning, and therefore the above explanation is made.

CHARLES S. PROSSER.

COLUMBUS, OHIO,
March, 1902.

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[1] Letter of February 28, 1902.

[2] Vol. IX, 1891, p. 206.